

Analysis Update: Time of Flight (ToF) with MURAVES Data

Oct. 18, 2022

Samip Basnet
(w/ Gigi)

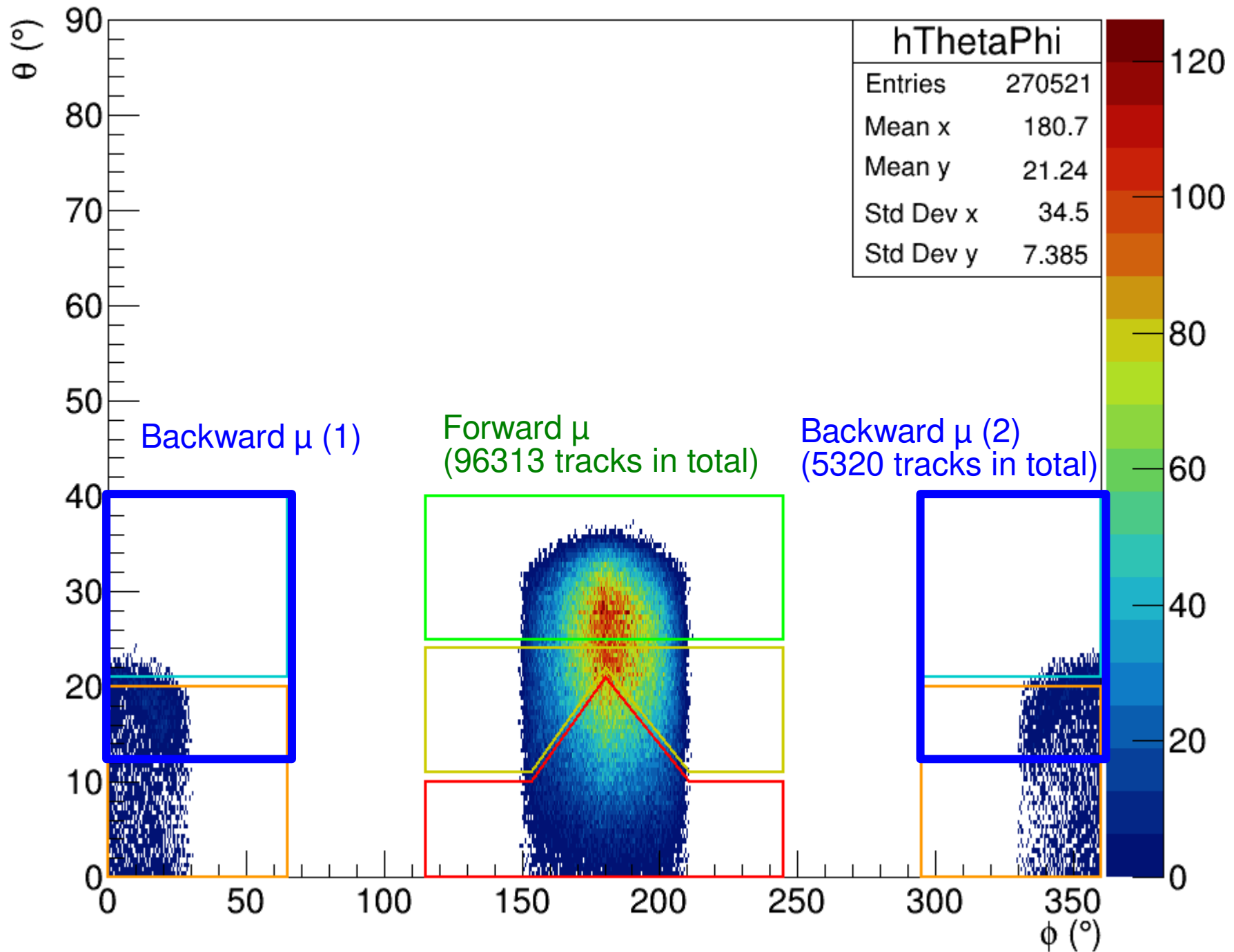


European
Commission

Horizon 2020
European Union funding
for Research & Innovation



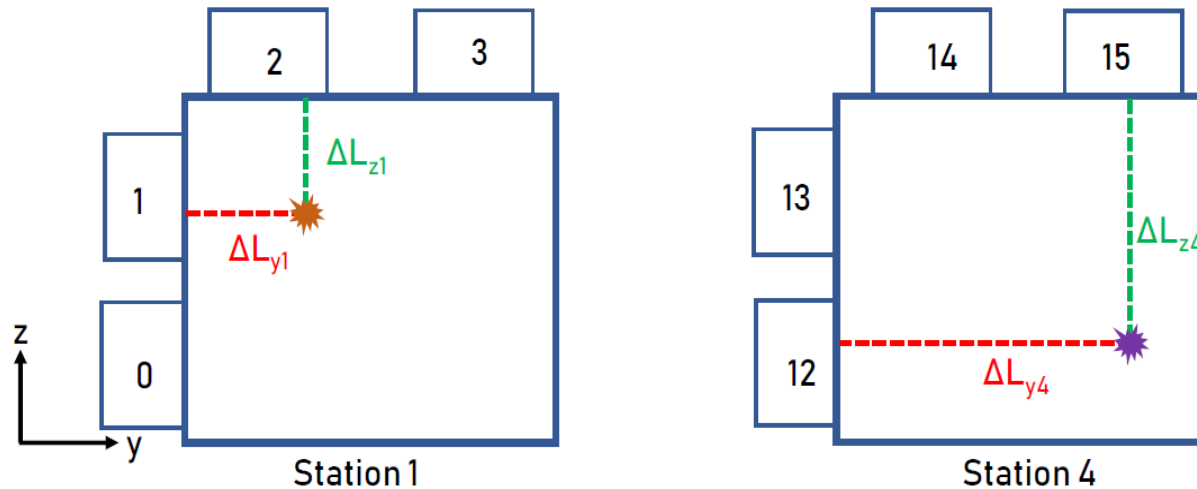
θ - ϕ (BLU)



BLU Data used : Free-sky runs #8820 – 9543 (270521 “golden” tracks)

• Measured ToF

Fiber-delay addition:



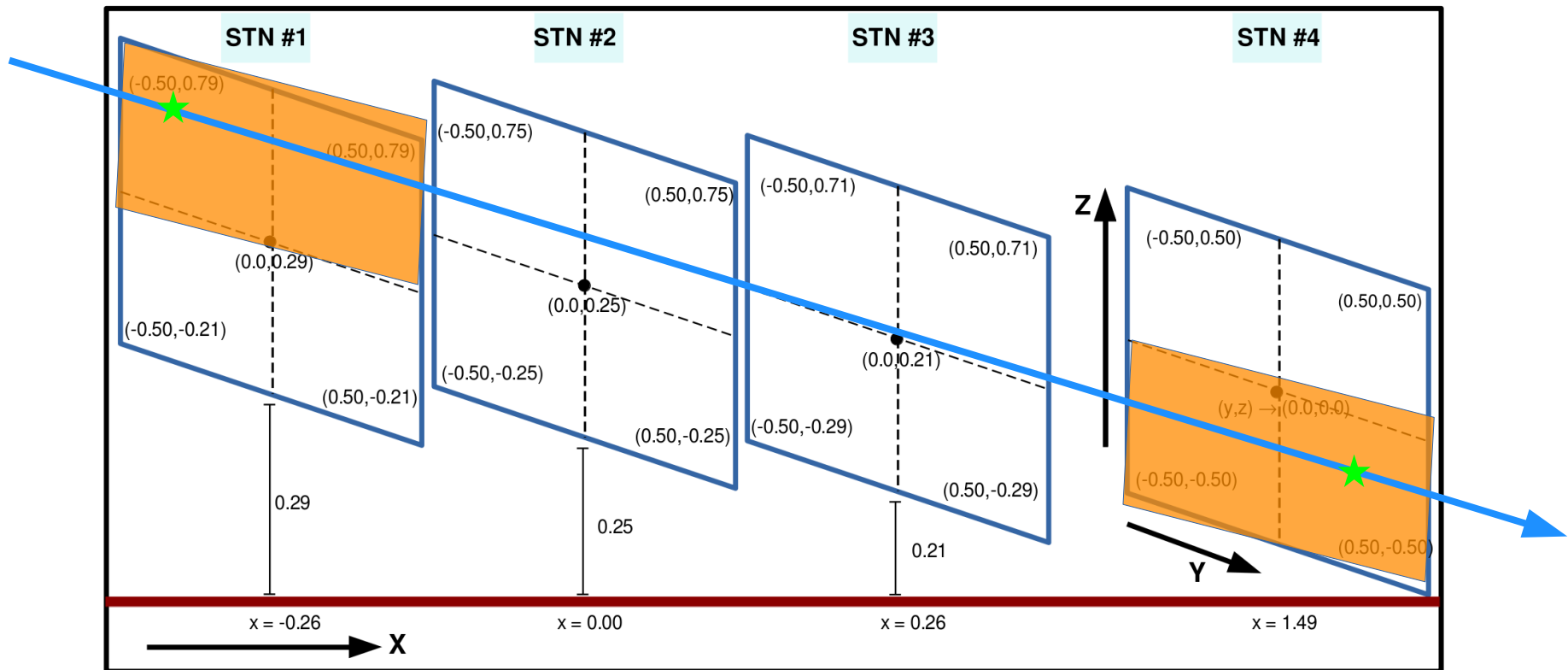
For XX view:
$$ToF_X = \left(\frac{(T_{1X} - T_1^0)}{E_1} + \frac{\Delta L_{y1}}{v_{fiber}} \right) - \left(\frac{(T_{4X} - T_4^0)}{E_4} + \frac{\Delta L_{y4}}{v_{fiber}} \right)$$

For YY view:
$$ToF_Y = \left(\frac{(T_{1Y} - T_1^0)}{E_1} + \frac{\Delta L_{z1}}{v_{fiber}} \right) - \left(\frac{(T_{4Y} - T_4^0)}{E_4} + \frac{\Delta L_{z4}}{v_{fiber}} \right)$$

- Adjust the equations above accordingly for XY and YX views ToF (w/ delay) calculation.

- **Expected ToF** is calculated based on the detector geometry and reconstructed angular information
- **ΔToF** is the difference between measured and expected ToFs

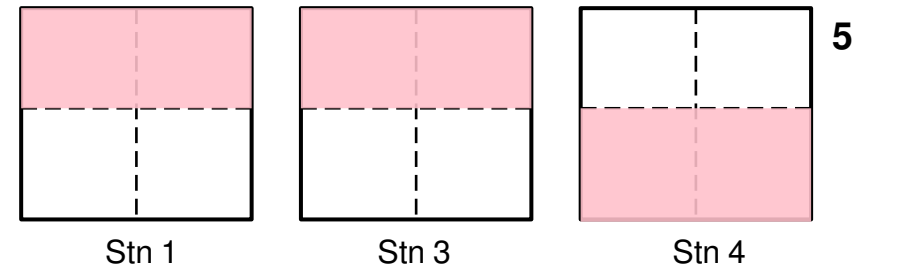
“Forward” μ



Note : The units of all the lengths in this slide are in meter.

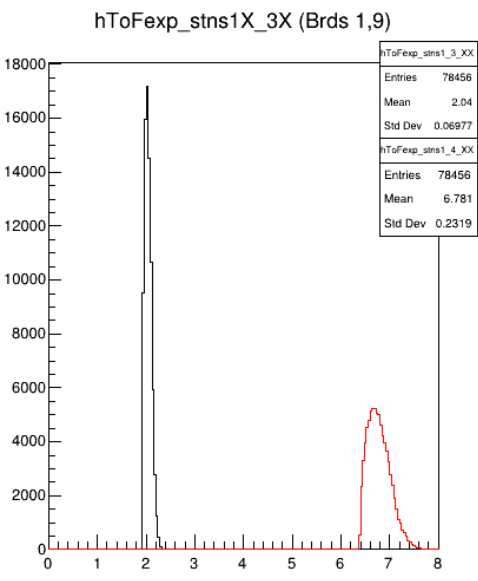
XX view

Boards 1,9 for Stns 1-3 
Boards 1,12 for Stns 1-4 

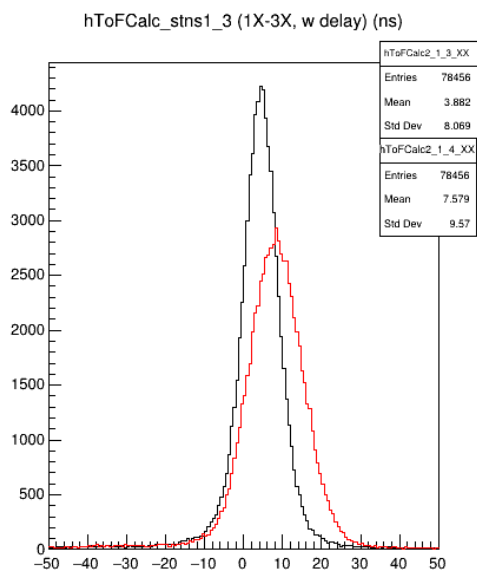


5

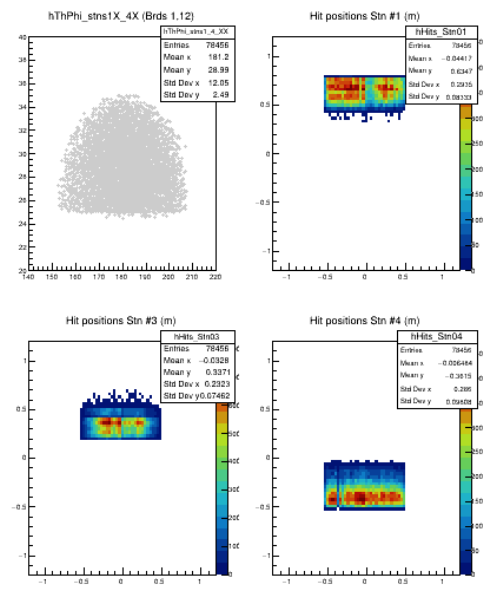
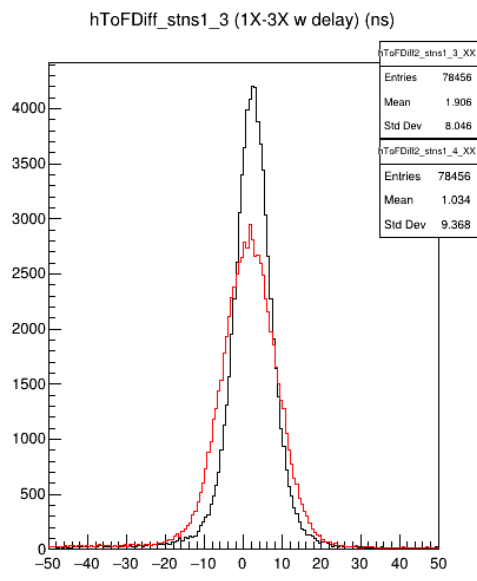
Expected ToF



Measured ToF



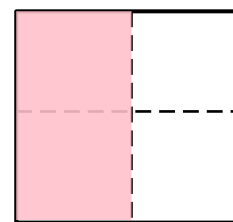
Δ ToF



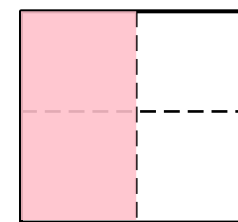
YY view (#1)

6

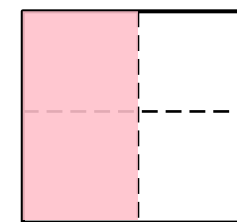
Boards 2,10 for Stns 1-3
Boards 2,14 for Stns 1-4



Stn 1



Stn 3



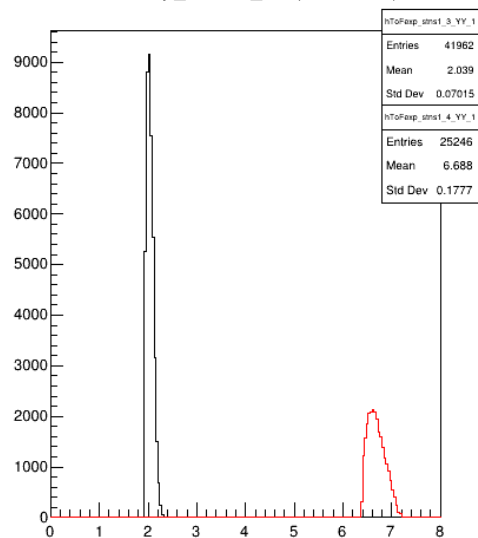
Stn 4

Expected ToF

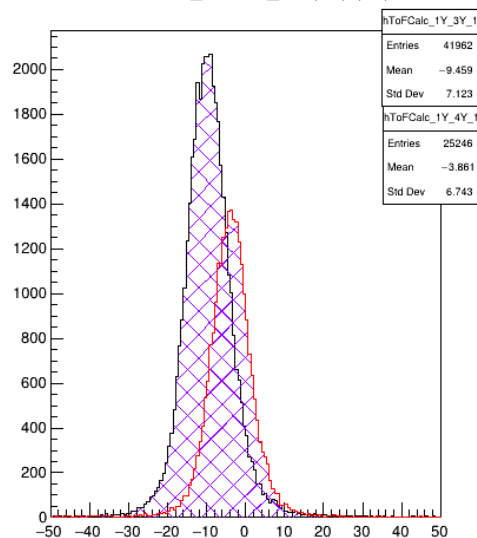
Measured ToF

Δ ToF

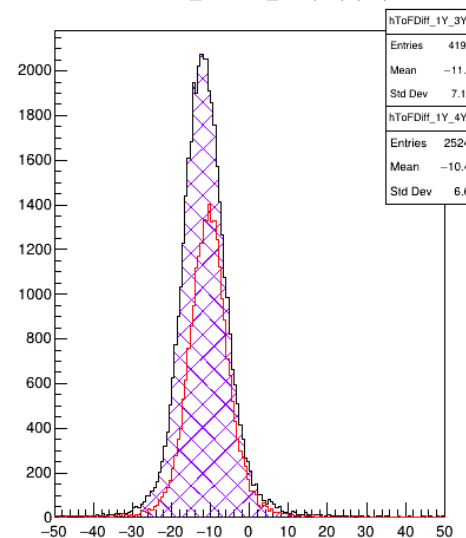
hToFexp_stns1Y_3Y (Brds 2,10)



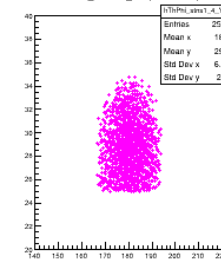
hToFCalc_stns1Y_3Y (#1) (ns)



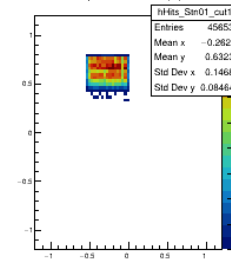
hToFDiff_stns1Y_3Y (#1) (ns)



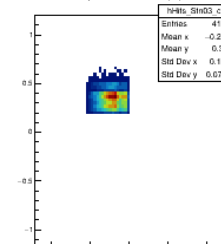
hThPhi_stns1_4_YY_1



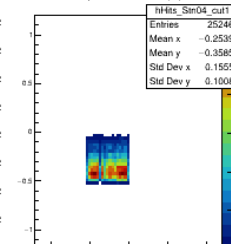
Hit positions Stn #1 (m)



Hit positions Stn #3 (m)



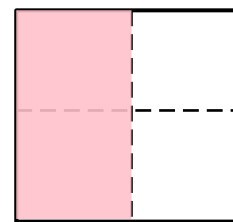
Hit positions Stn #4 (m)



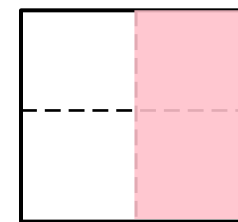
YY view (#2)

7

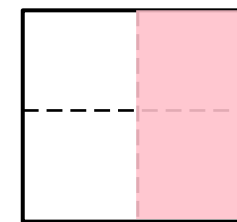
Boards 2,11 for Stns 1-3
Boards 2,15 for Stns 1-4



Stn 1



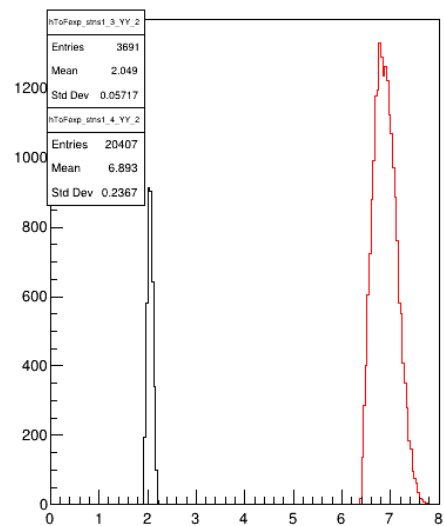
Stn 3



Stn 4

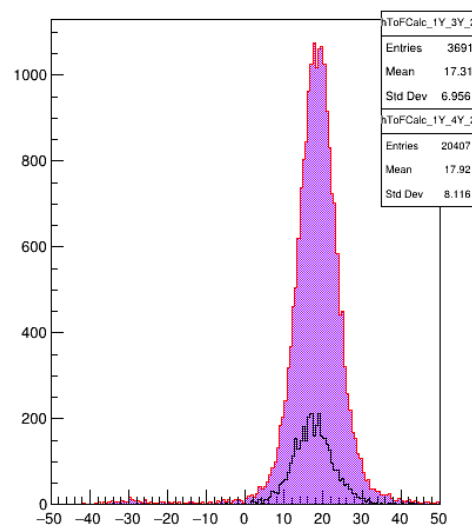
Expected ToF

hToFexp_stns1Y_4Y (Brds 2,15)



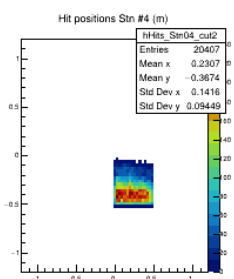
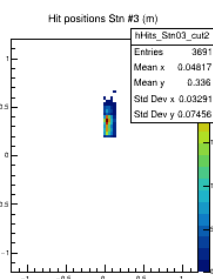
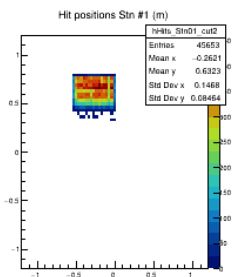
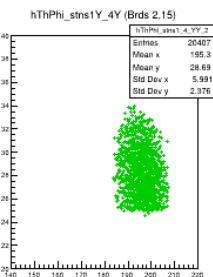
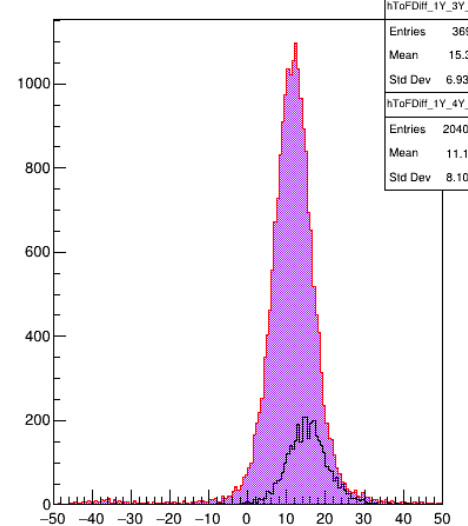
Measured ToF

hToFCalc_stns1Y_4Y (#2) (ns)



Δ ToF

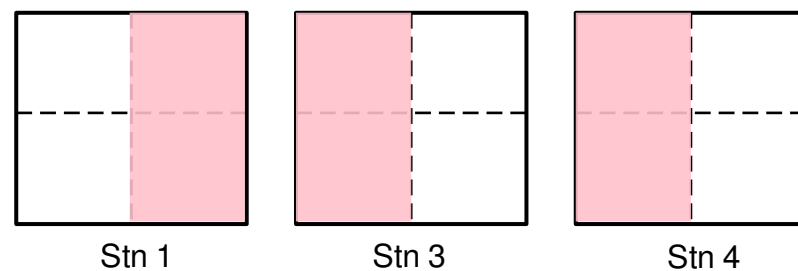
hToFDiff_stns1Y_4Y (#2) (ns)



YY view (#3)

8

Boards 3,10 for Stns 1-3
Boards 3,14 for Stns 1-4

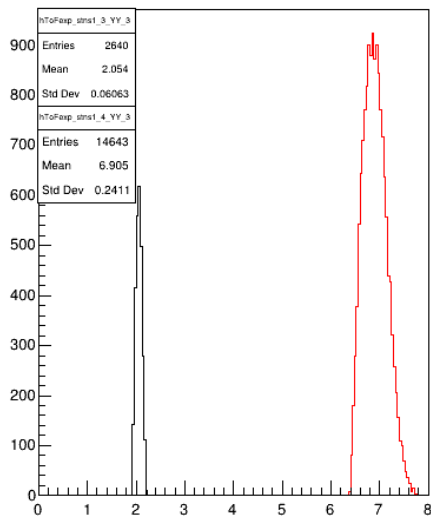


Expected ToF

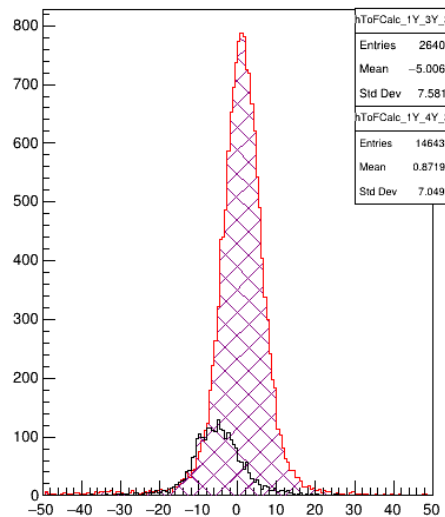
Measured ToF

Δ ToF

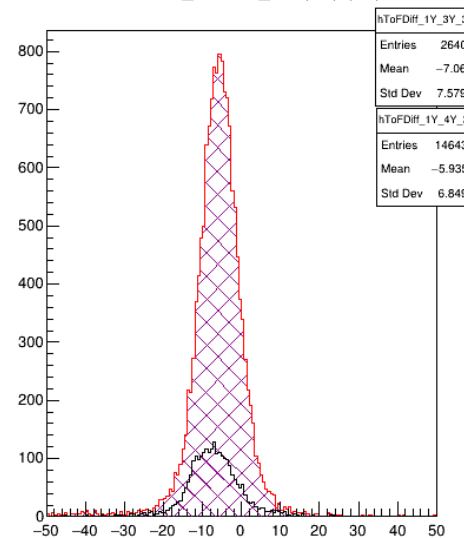
hToFexp_stns1Y_4Y (Brds 3,14)



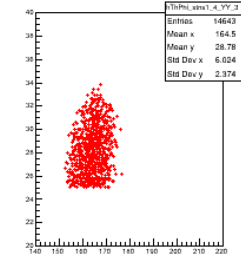
hToFCalc_stns1Y_4Y (#3) (ns)



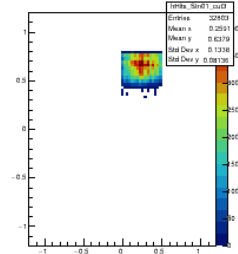
hToFDiff_stns1Y_4Y (#3) (ns)



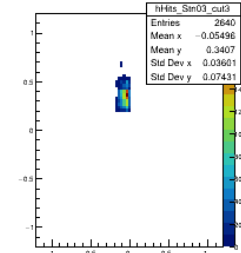
hThPhi_stns1Y_4Y (Brds 3,14)



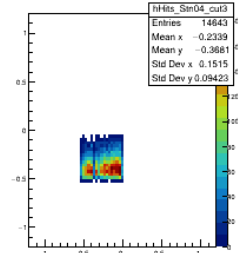
Hit positions Stn #1 (m)



Hit positions Stn #3 (m)



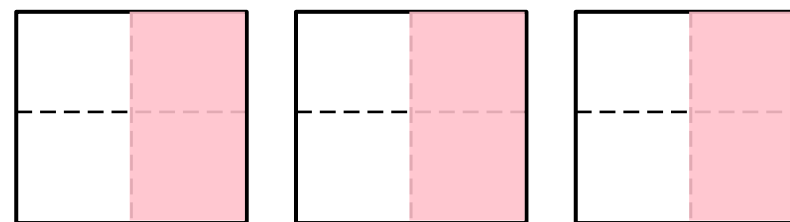
Hit positions Stn #4 (m)



YY view (#4)

9

Boards 3,11 for Stns 1-3
Boards 3,15 for Stns 1-4



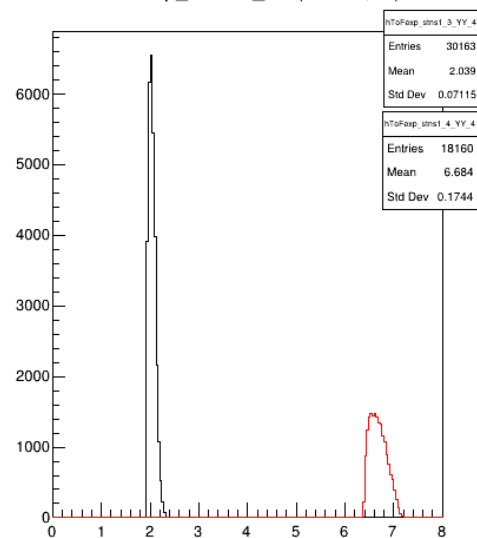
Stn 1

Stn 3

Stn 4

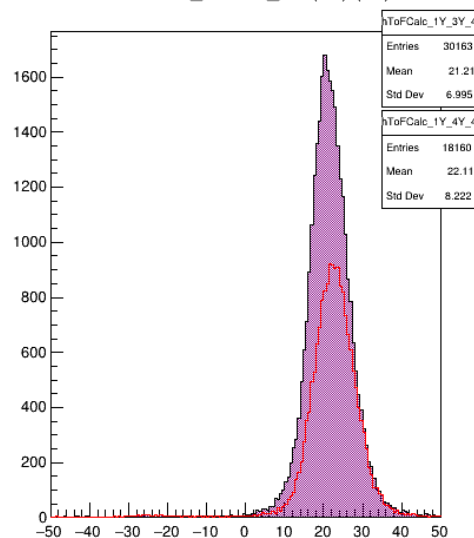
Expected ToF

hToFexp_stns1Y_3Y (Brds 3,11)



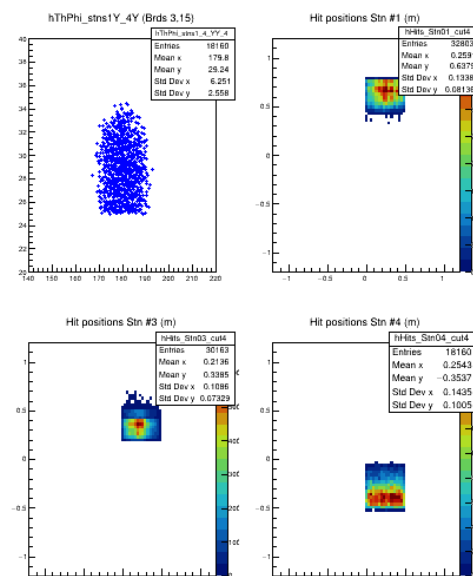
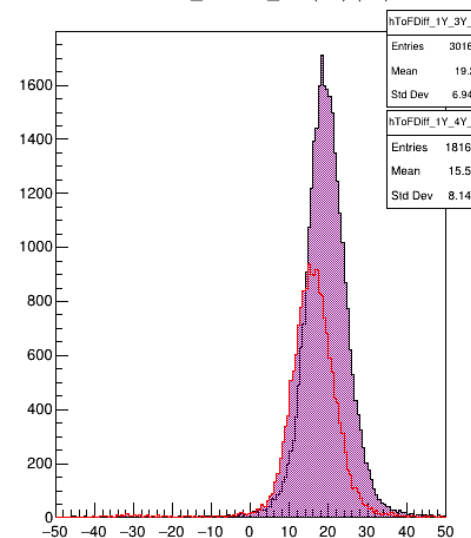
Measured ToF

hToFCalc_stns1Y_3Y (#4) (ns)



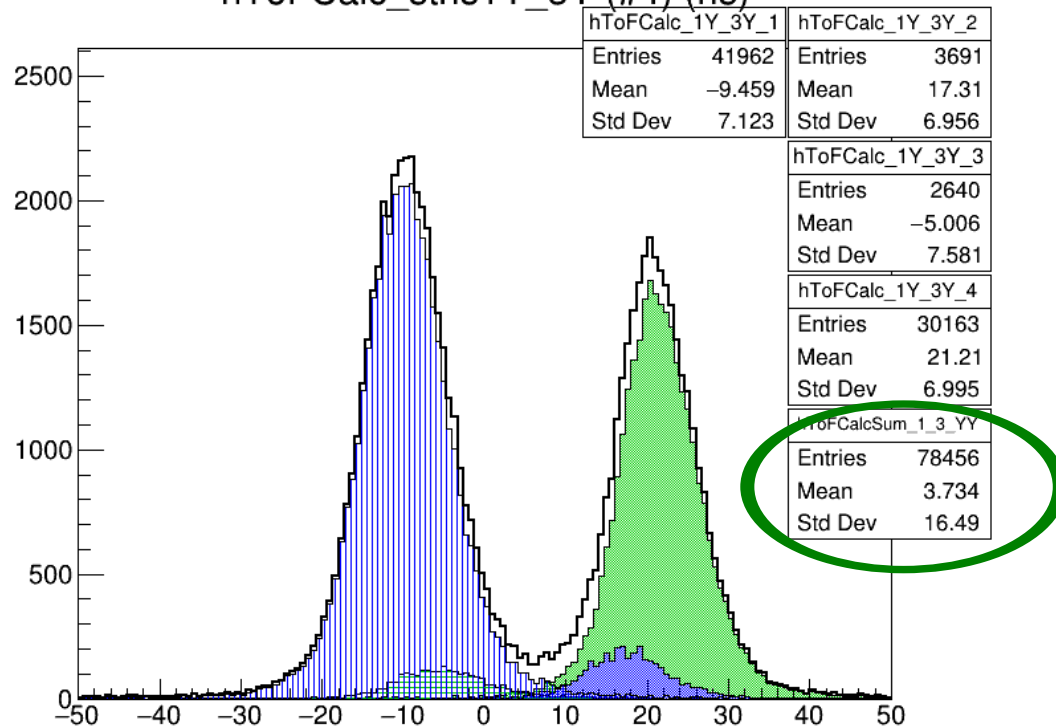
Δ ToF

hToFDiff_stns1Y_3Y (#4) (ns)

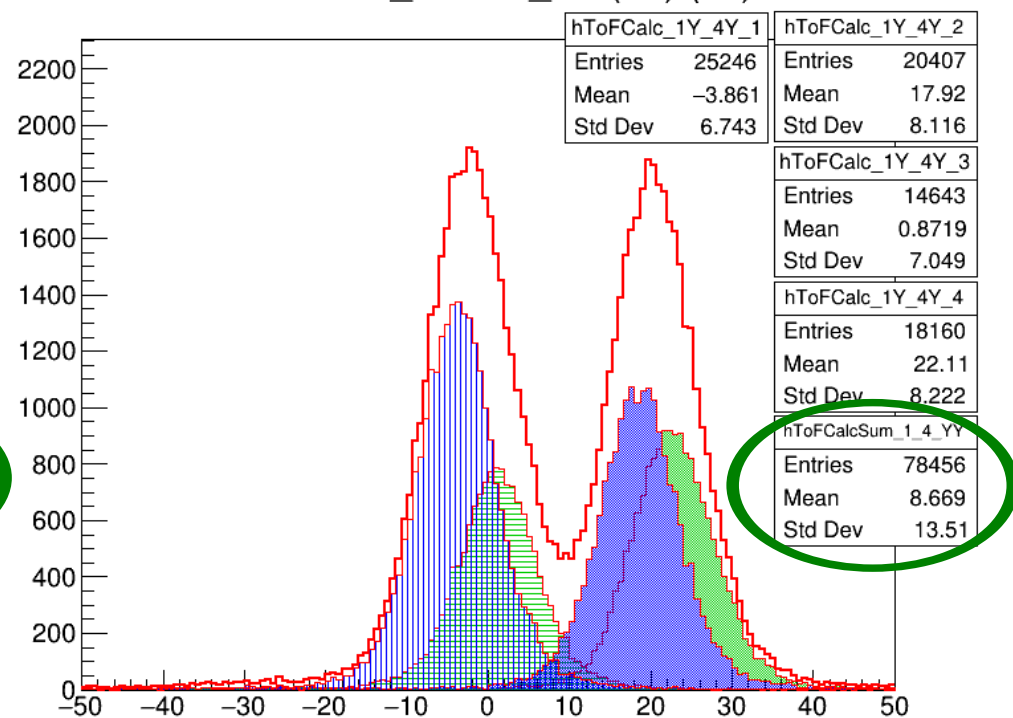


Measured ToF

hToFCalc_stns1Y_3Y (#4) (ns)



hToFCalc_stns1Y_4Y (#4) (ns)



— Stations 1 - 3

— Stations 1 - 4

- Good measured ToF when all 4 Y-views results are combined.
- ***NOT VALID WHEN FIBER-DELAY COMPONENT IS SUBTRACTED!***

Summary

11

Region	Stations 1 – 3				Stations 1 – 4			
	Boards involved	ToF _{exp} (ns)	ToF _{mes} (ns)	ΔToF (ns)	Boards involved	ToF _{exp} (ns)	ToF _{mes} (ns)	ΔToF (ns)
X-View	<i>1, 9</i>	2.04	3.88	1.91	<i>1, 12</i>	6.78	7.58	1.04
Y-View	<i>2, 10</i>	2.04	-9.46	-11.46	<i>2, 14</i>	6.68	-3.86	-10.46
	<i>2, 11</i>	2.05	17.31	15.31	<i>2, 15</i>	6.89	17.92	11.14
	<i>3, 10</i>	2.05	-5.00	-7.06	<i>3, 14</i>	6.91	0.87	-5.93
	<i>3, 11</i>	2.04	21.21	19.21	<i>3, 15</i>	6.68	22.11	15.55

**Y-view
combined**

2.04

3.73

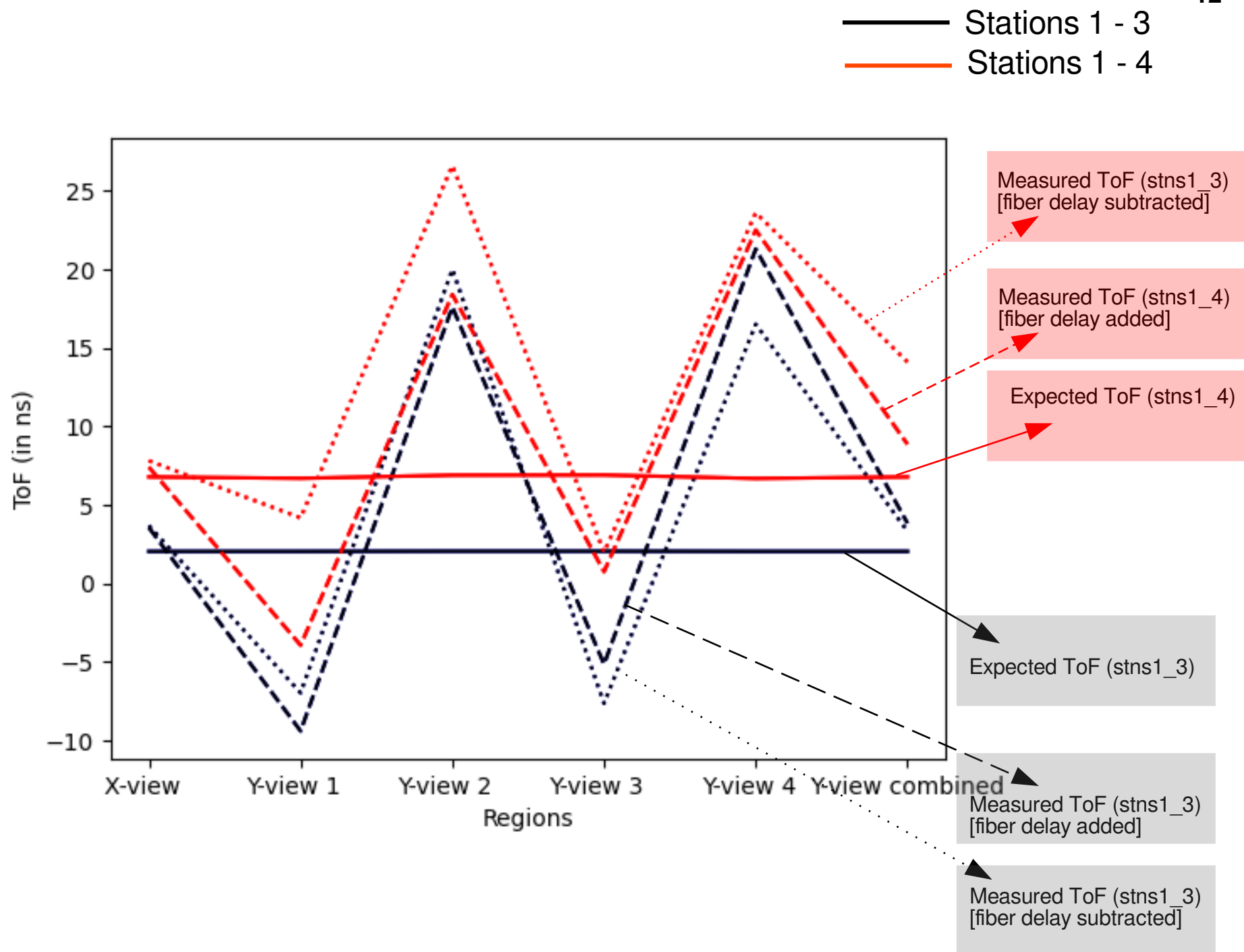
1.74

6.78

8.67

2.01

(Only for BLU)



Summary

(without using the intercept values; only expansion factors used)

Region	Stations 1 – 3				Stations 1 – 4			
	Boards involved	ToF _{exp} (ns)	ToF _{mes} (ns)	ΔToF (ns)	Boards involved	ToF _{exp} (ns)	ToF _{mes} (ns)	ΔToF (ns)
X-View	1, 9	2.04	1.75	-0.24	1, 12	6.78	5.72	-1.05
		2.05	8.43	6.39		6.80	7.60	0.85
		2.05	8.10	6.05		6.83	11.07	4.27
Y-View	2, 10	2.04	-17.00	-19.02	2, 14	6.68	-10.62	-17.19
		2.05	-20.64	-22.66		6.71	-1.77	-8.21
		2.06	-30.71	-32.74		6.74	-28.35	-34.95
	2, 11	2.05	2.23	0.21	2, 15	6.89	3.22	-3.37
		2.06	-14.73	-16.76		6.91	-18.59	-25.35
		2.07	-12.80	-14.85		6.95	-13.42	-20.31
	3, 10	2.05	-8.83	-10.85	3, 14	6.91	-2.09	-8.88
		2.06	12.02	9.98		6.91	30.81	24.77
		2.07	-9.32	-11.37		6.94	-6.47	-13.35
	3, 11	2.04	9.88	7.86	3, 15	6.68	11.19	4.65
		2.04	17.32	15.30		6.71	14.90	8.27
		2.05	8.11	6.07		6.72	7.94	1.26

**Y-view
combined**

2.04
2.05
2.05

-5.48
-0.44
-14.22

-7.50
-2.46
-16.25

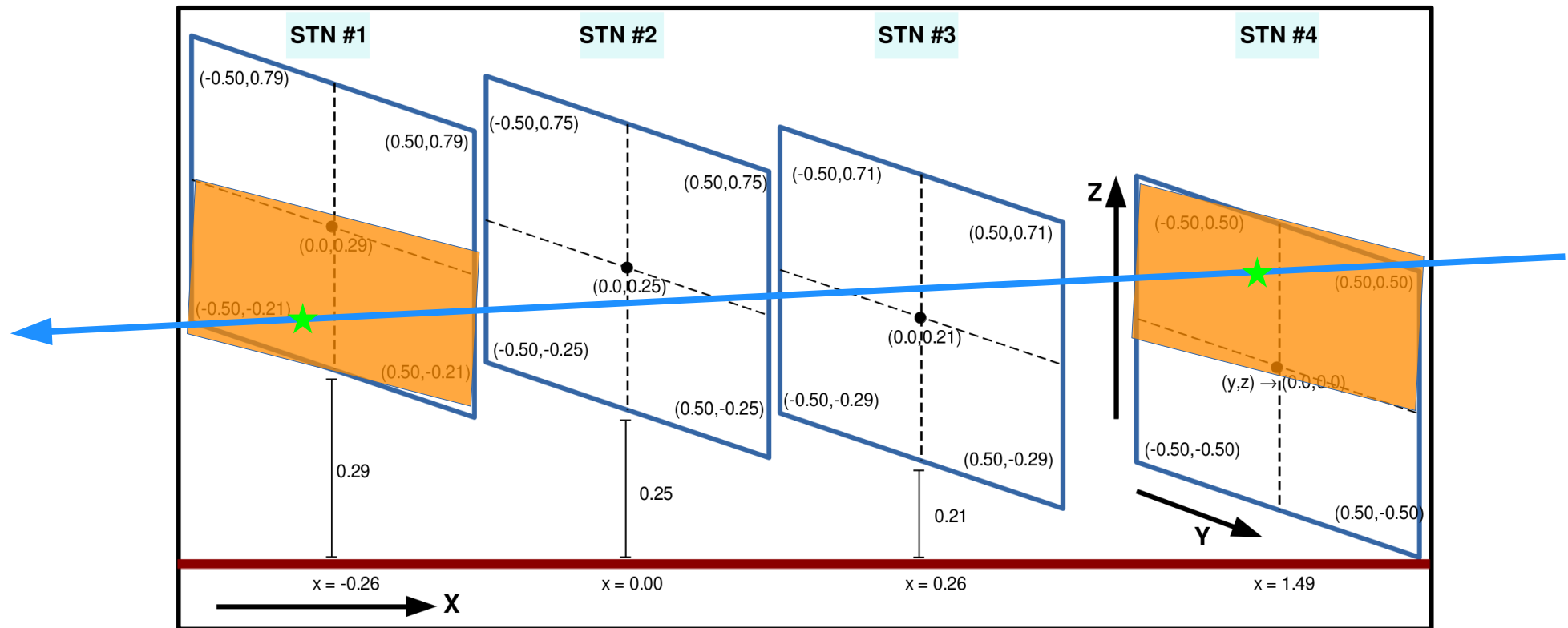
6.78
6.71
6.83

-0.39
6.35
-11.98

-7.00
0.07
-18.72

Results are color coded. (i.e., **BLU**, **NERO**, **ROSSO**)

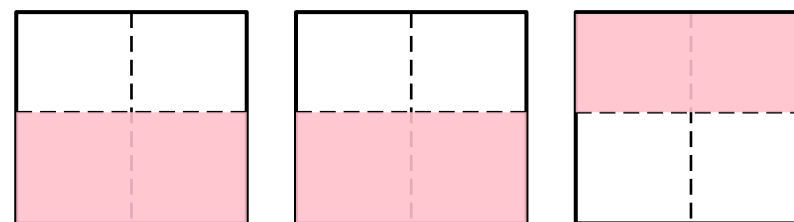
“Backward” μ



Note : The units of all the lengths in this slide are in meter.

XX view

Boards 0,8 for Stns 1-3
Boards 0,13 for Stns 1-4



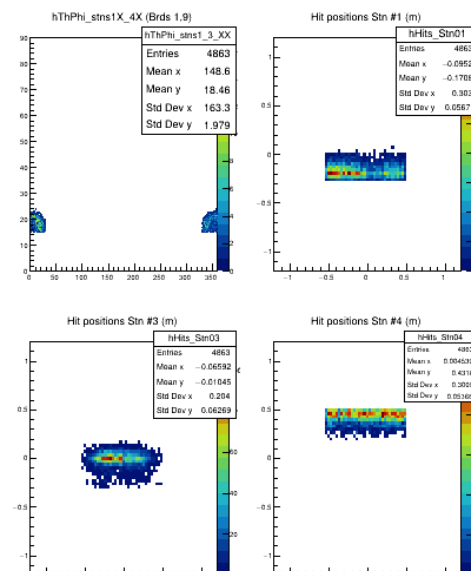
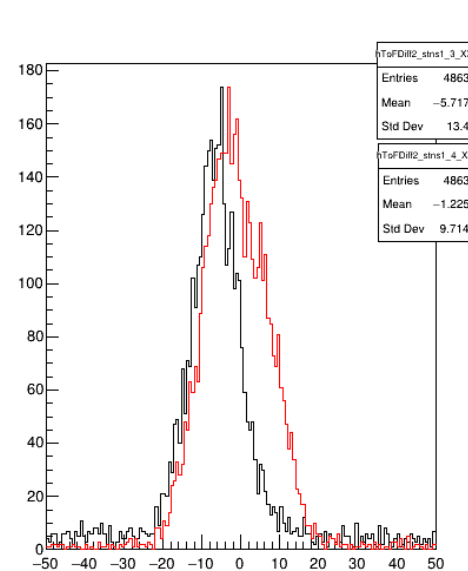
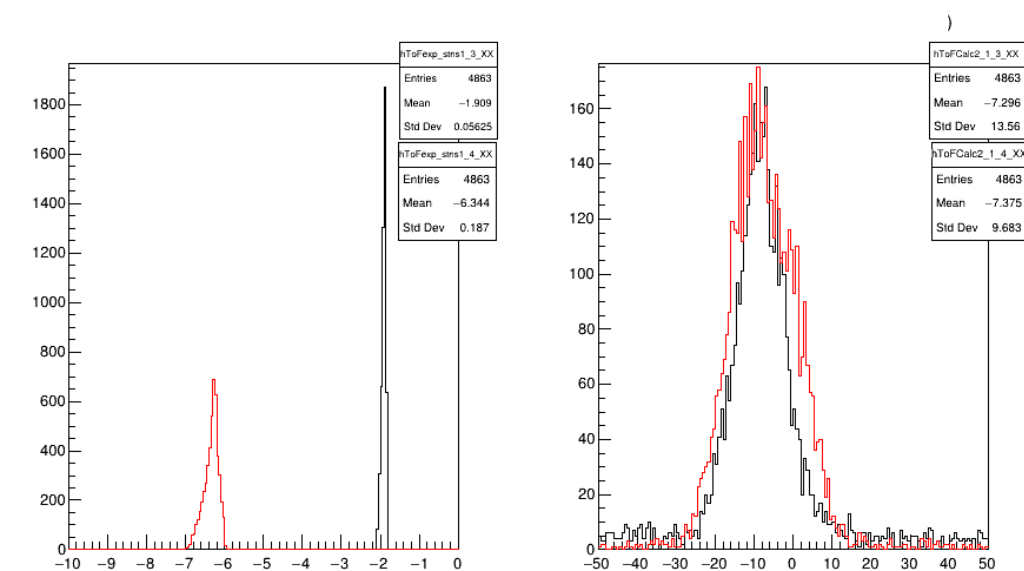
Stn 1

Stn 3

Stn 4

Expected ToF

Measured ToF

 ΔToF 

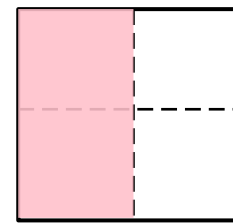
— Stations 1 - 3

— Stations 1 - 4

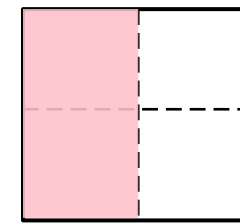
YY view (#1)

16

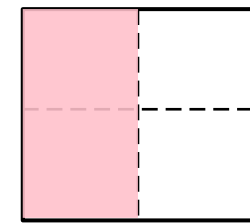
Boards 2,10 for Stns 1-3
Boards 2,14 for Stns 1-4



Stn 1



Stn 3

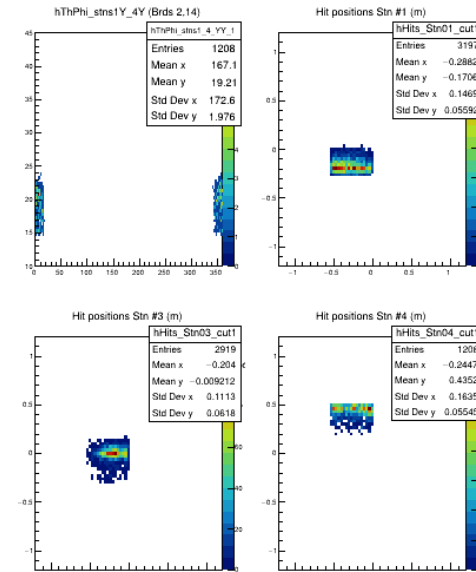
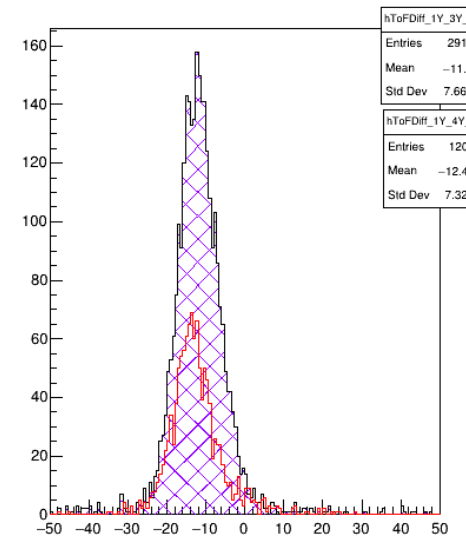
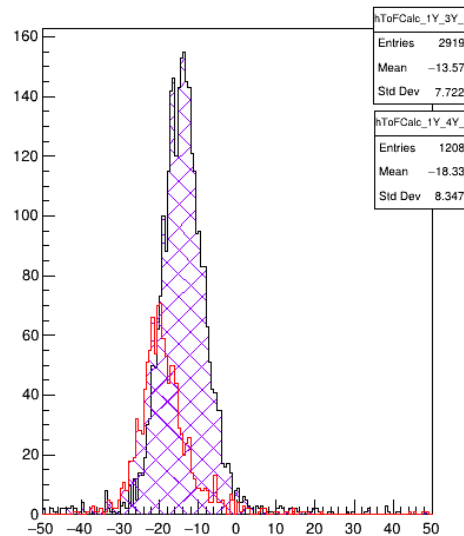
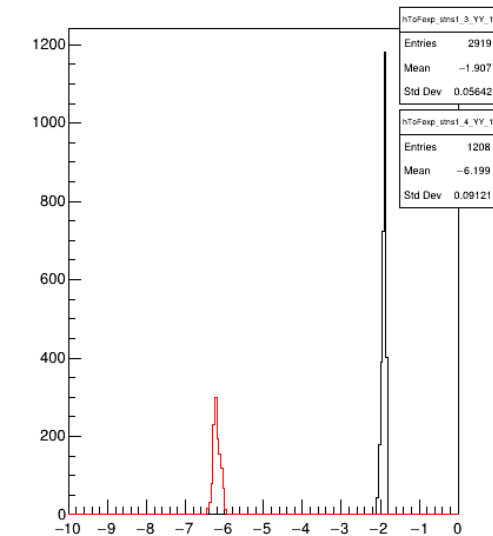


Stn 4

Expected ToF

Measured ToF

Δ ToF



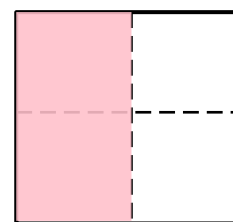
— Stations 1 - 3

— Stations 1 - 4

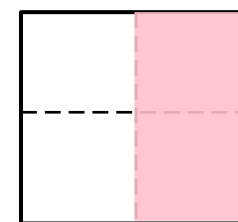
YY view (#2)

17

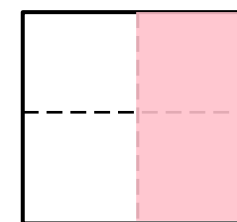
Boards 2,11 for Stns 1-3
Boards 2,15 for Stns 1-4



Stn 1



Stn 3

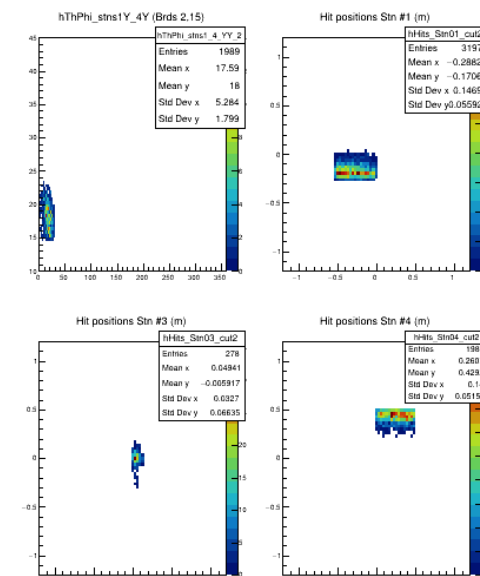
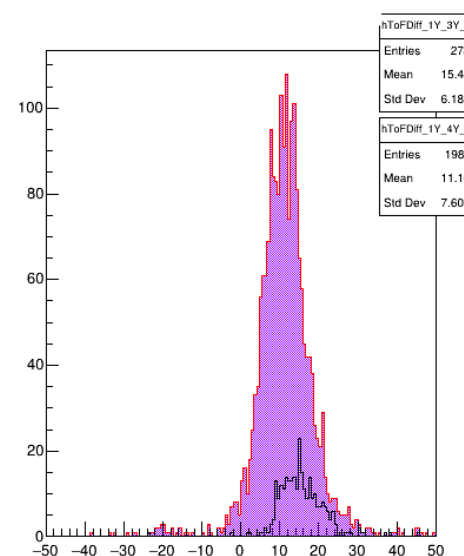
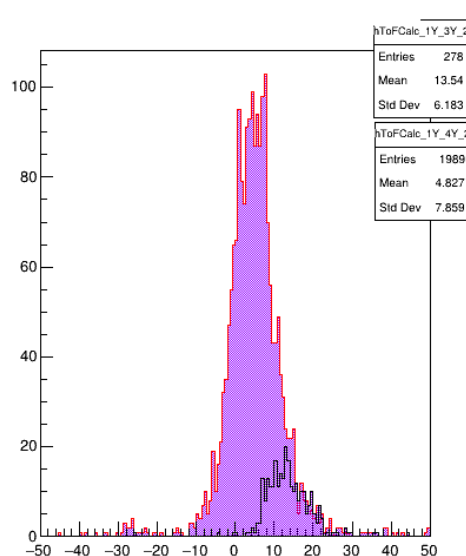
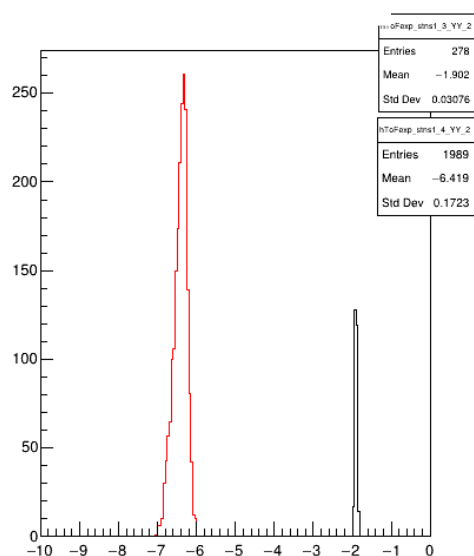


Stn 4

Expected ToF

Measured ToF

Δ ToF



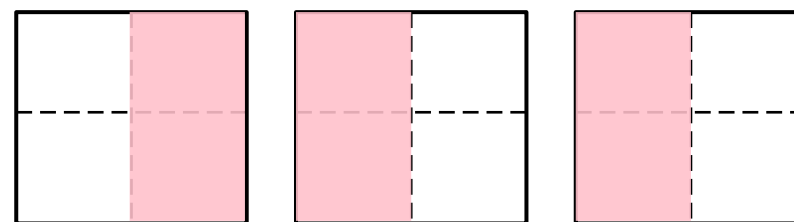
— Stations 1 - 3

— Stations 1 - 4

YY view (#3)

18

Boards 3,10 for Stns 1-3
Boards 3,14 for Stns 1-4



Stn 1

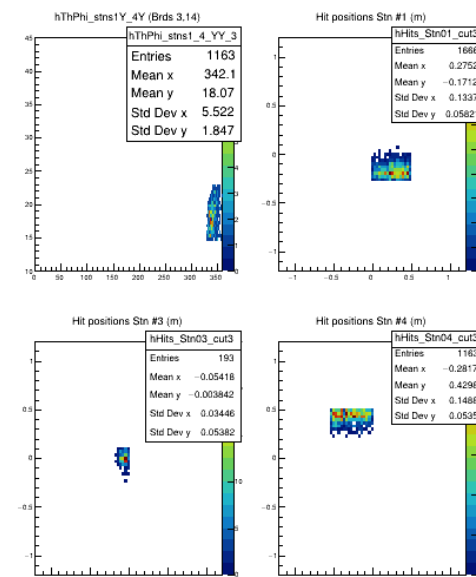
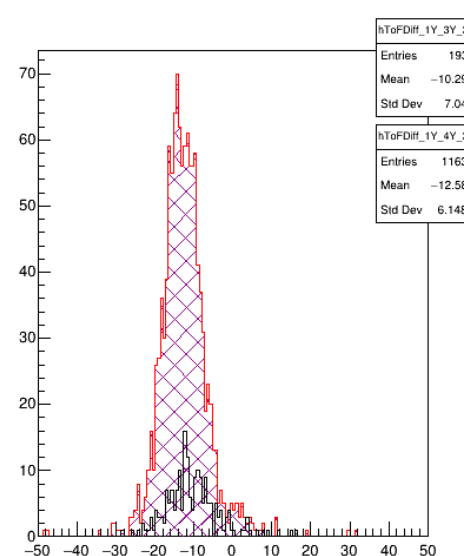
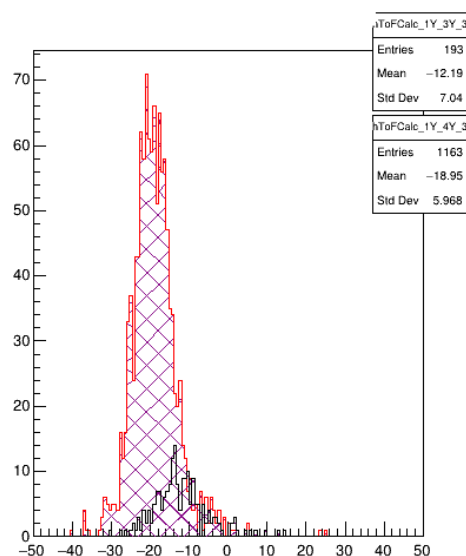
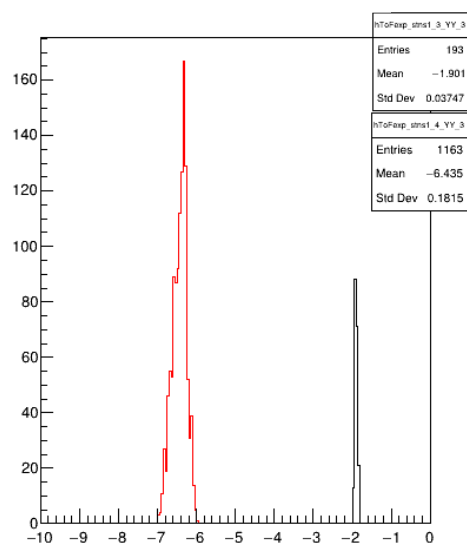
Stn 3

Stn 4

Expected ToF

Measured ToF

Δ ToF



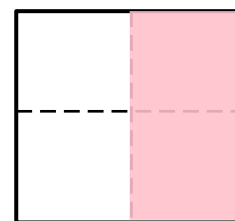
— Stations 1 - 3

— Stations 1 - 4

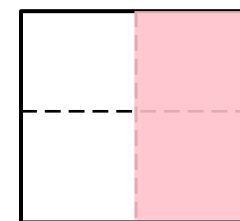
YY view (#4)

19

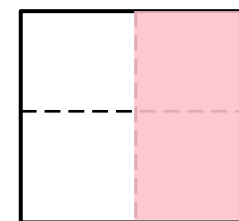
Boards 3,11 for Stns 1-3
Boards 3,15 for Stns 1-4



Stn 1



Stn 3

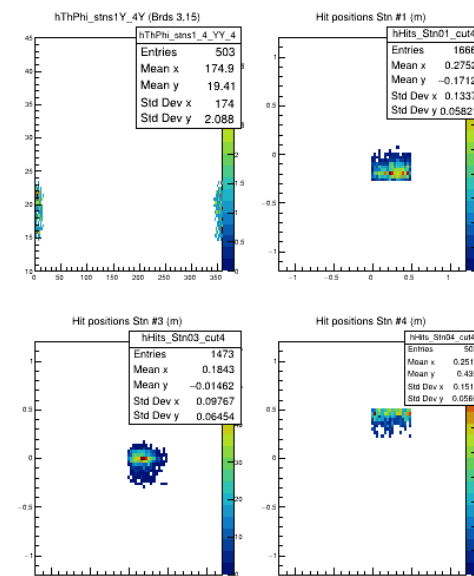
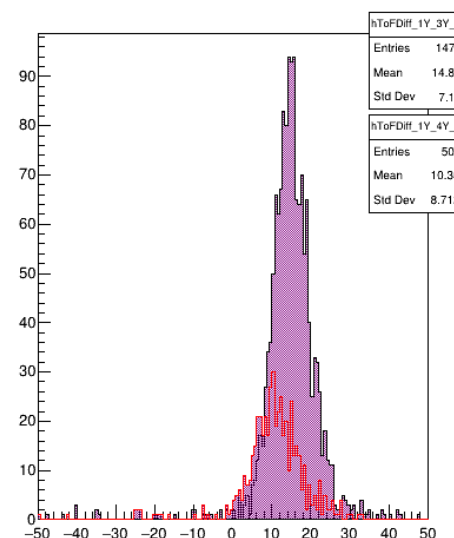
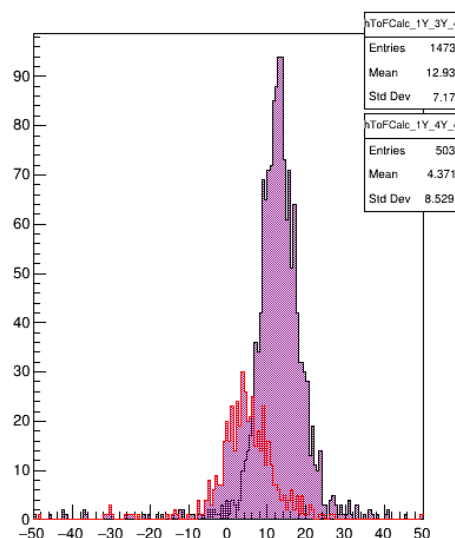
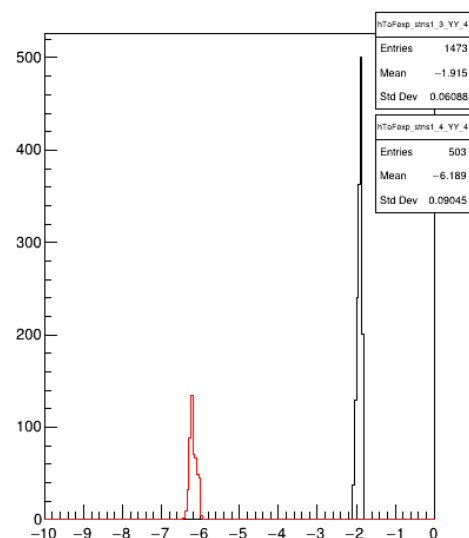


Stn 4

Expected ToF

Measured ToF

ΔToF

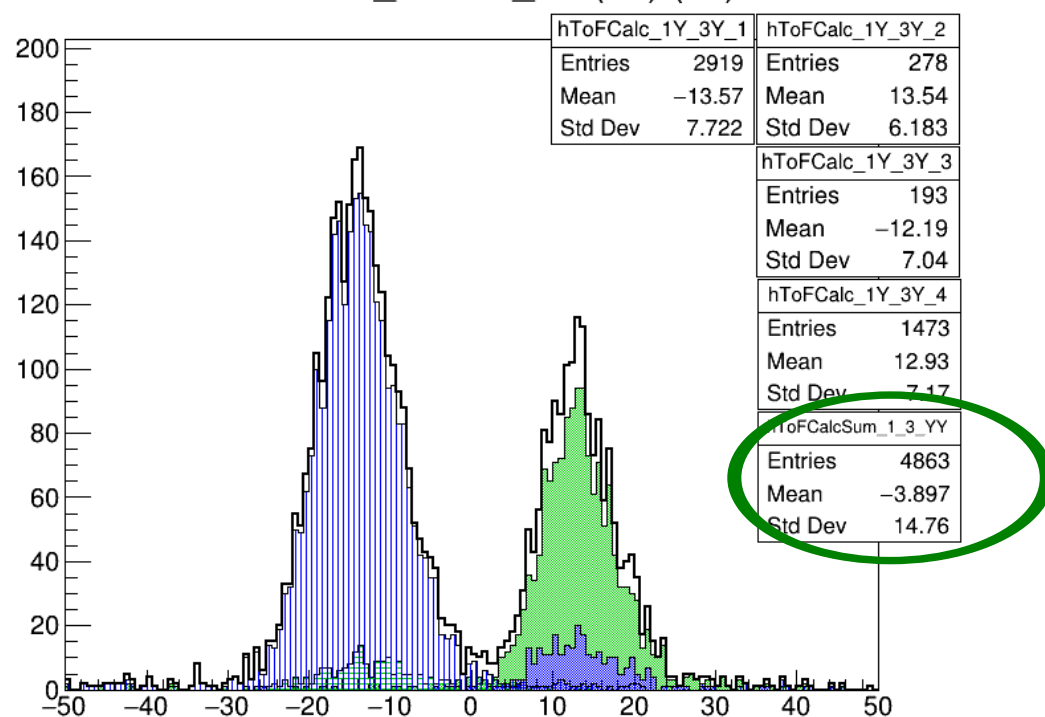


— Stations 1 - 3

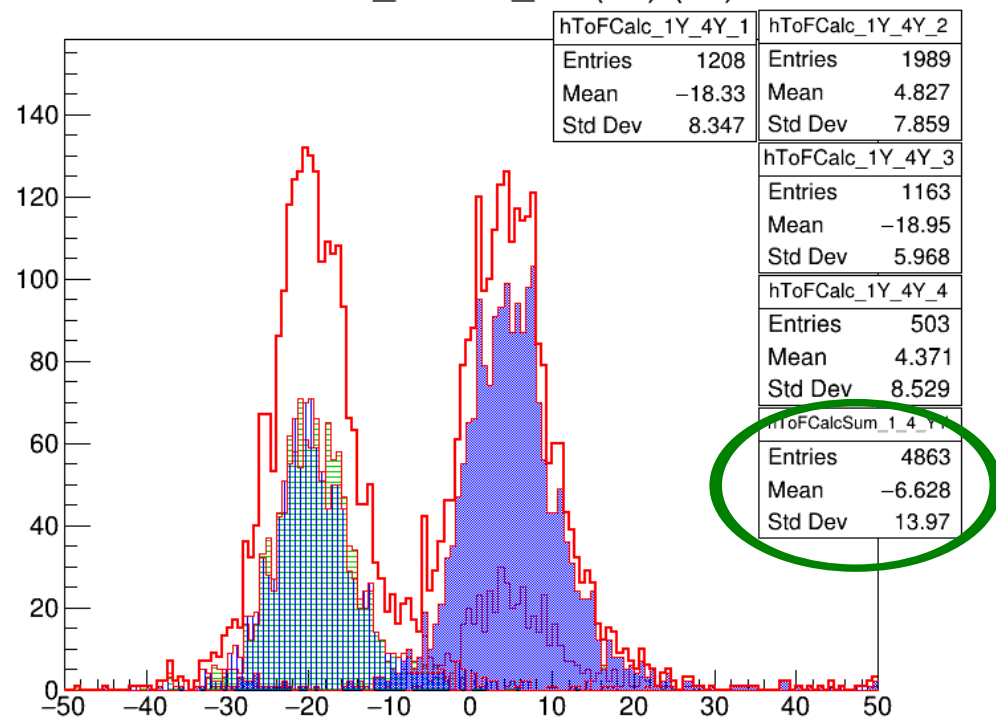
— Stations 1 - 4

Measured ToF

hToFCalc_stns1Y_3Y (#4) (ns)



hToFCalc_stns1Y_4Y (#4) (ns)



— Stations 1 - 3

— Stations 1 - 4

Summary

21

Region	Stations 1 – 3				Stations 1 – 4			
	Boards involved	ToF _{exp} (ns)	ToF _{mes} (ns)	ΔToF (ns)	Boards involved	ToF _{exp} (ns)	ToF _{mes} (ns)	ΔToF (ns)
X-View	<i>0, 8</i>	-1.91	-7.30	-5.71	<i>0, 13</i>	-6.34	-7.38	-1.22
Y-View	<i>2, 10</i>	-1.91	-13.57	-11.70	<i>2, 14</i>	-6.20	-18.33	-12.47
	<i>2, 11</i>	-1.90	13.54	15.44	<i>2, 15</i>	-6.42	4.83	11.16
	<i>3, 10</i>	-1.90	-12.19	-10.29	<i>3, 14</i>	-6.44	-12.58	-5.93
	<i>3, 11</i>	-1.92	12.93	14.85	<i>3, 15</i>	-6.18	4.37	10.35

**Y-view
combined**

-1.91

-3.90

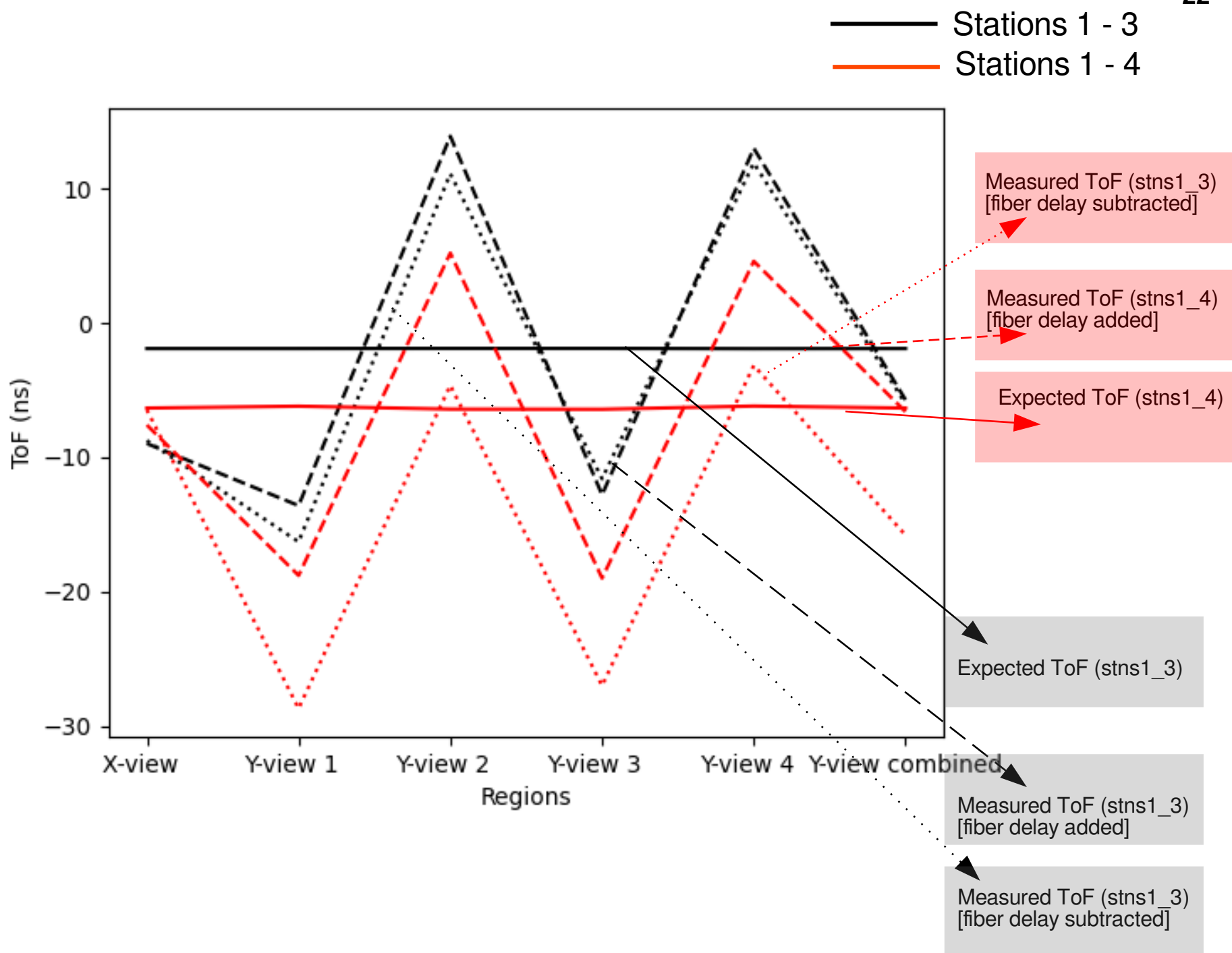
-2.01

-6.34

-6.62

-0.44

(Only for BLU)



Summary

(without using the intercept values; only expansion factors used)

Region	Stations 1 – 3				Stations 1 – 4			
	Boards involved	ToF _{exp} (ns)	ToF _{mes} (ns)	ΔToF (ns)	Boards involved	ToF _{exp} (ns)	ToF _{mes} (ns)	ΔToF (ns)
X-View	0, 8	-1.91	-9.22	-7.51	0, 13	-6.34	-10.26	-3.92
		-1.91	-1.54	0.36		-6.34	-11.28	-4.97
		-1.91	2.33	4.24		-6.35	-4.02	2.33
Y-View	2, 10	-1.91	-21.12	-19.29	2, 14	-6.20	-25.18	-19.47
		-1.91	-24.04	-22.66		-6.19	-13.87	-7.57
		-1.91	-12.86	-10.94		-6.20	-19.93	-13.80
	2, 11	-1.90	-1.67	0.42	2, 15	-6.42	-9.99	-3.35
		-1.90	-19.28	-17.42		-6.41	-34.68	-28.32
		-1.90	-14.63	-12.73		-6.43	-5.92	0.51
	3, 10	-1.90	-16.01	-14.73	3, 14	-6.44	-21.90	-15.55
		-1.90	2.13	4.05		-6.42	13.41	20.14
		-1.91	21.76	23.67		-6.45	16.03	22.45
	3, 11	-1.92	1.52	3.39	3, 15	-6.19	-6.53	-0.35
		-1.91	7.57	9.51		-6.19	-6.69	-0.38
		-1.91	19.21	21.12		-6.20	29.77	35.95

Y-view combined	-1.91	-12.91	-11.11	-6.34	-16.23	-9.96
	-1.91	-7.69	-5.80	-6.34	-10.73	-4.28
	-1.91	3.88	5.79	-6.35	6.01	12.35

Results are color coded. (i.e., **BLU**, **NERO**, **ROSSO**)