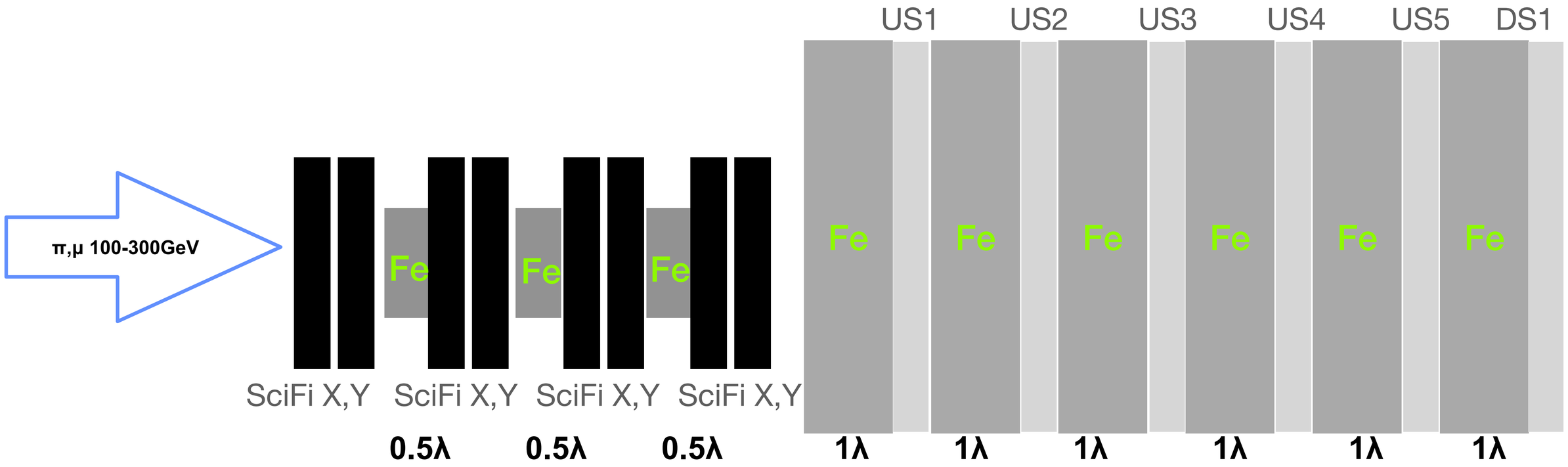
HCAL test beam data analysis work plan

Notebook 2023.10.24 (M.Dallavalle INFN/BO)



Preamble

- Pion interaction length λint in iron = 20.4 cm
- shower observables: depth, width, integral (or samplings)
- ~90% of the energy within a cylinder of 1 λint radius; hadronic showers have a narrower EM core (π^0's)
    - test-beam-SciFi stations are 13by13 cm^2
- Depth of shower increase as logE: 95% at 100 GeV contained in 6 λint; at 300 GeV in 7.4 λint

- observables proportional to number of particles in the shower at a given z: **NhitsSciFi, TotalQDCUS**
    - a SciFiX (Y) plane has 512 channels read out by 8 TOFPETs

Tentative path towards a hadron shower energy measurement (since Gruyères', Sep 5)

1. US performance uniformity (S.Ilieva, O.Durhan, G.Soares, G.Vasquez)
    1. US calibration to MIP (S. Ilieva)
    2. negative QDCs (M. Climescu)
2. understand SciFi shower performance (C.Varela, M.Ferrillo)
3. algorithm to tag shower origin (S.Ilieva, G.Vasquez)
4. SciFi shower centroid algorithm (M. Climescu)
5. US shower centroid algorithm (G.Vasquez, M. Climescu)
6. Scifi vs US matching and relative calibration (M.Dallavalle)
7. calibration of small SiPMs (G.Vasquez)
8. Longitudinal shower profile (E.Ursov, E Khalilkov, F.Mei)
9. transverse shower profile in SciFi and in US (M. Climescu)
10. shower fit and E calibration: tabular method (origin, pion E, NhitsSciFi, totalQDCUS)(G.Vasquez)
11. shower fit and energy calibration: analytical method (M.Ferrillo, M.Dallavalle)
12. Shower simulations, simulations vs data (M. Climescu, E.Ursov, E Khalilkov)
13. Comparison to TI18 setup and tune Test Beam results for TI18 (S.Ilieva, G.Vasquez)

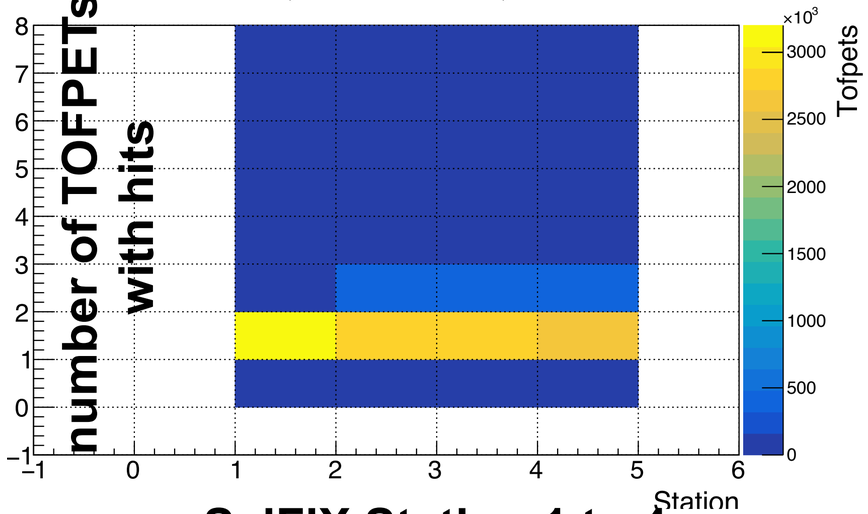
More contributors are welcome

ISSUE: SciFi: tofpet multiplicity per station

π fly through probability		
10 cm Fe	20 cm Fe	30 cm Fe
61%	38%	23%

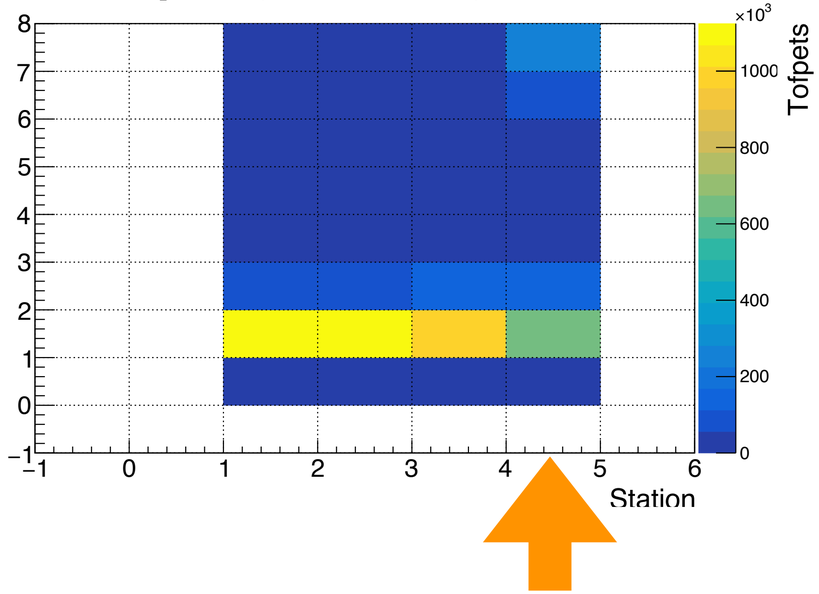
SciFiX planes; similarly for SciFiY

muon, 160 GeV, 3 walls

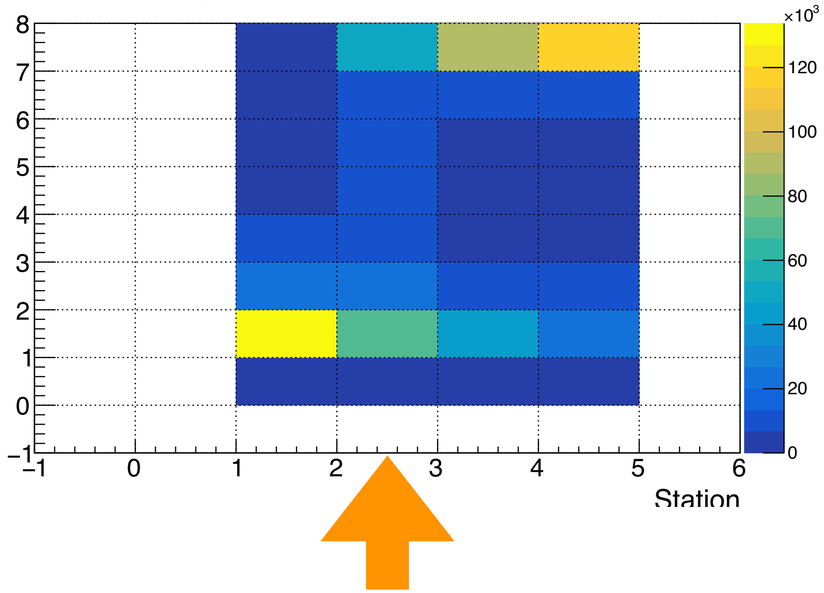


SciFiX Station 1 to 4

pion, 100 GeV, 1 wall



pion, 300 GeV, 3 wall



From their early development,

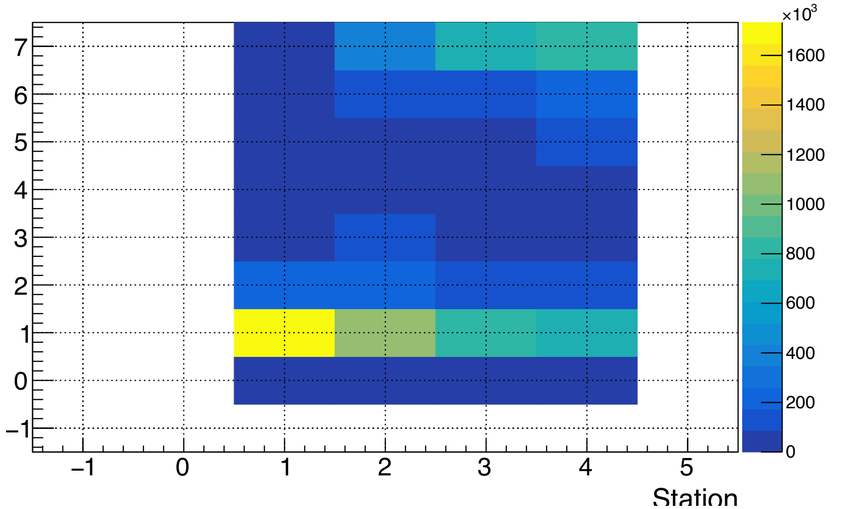
showers spread over the entire test-beam-SciFi acceptance, i.e. 8 TOPETs

target thickness influence vs E_π

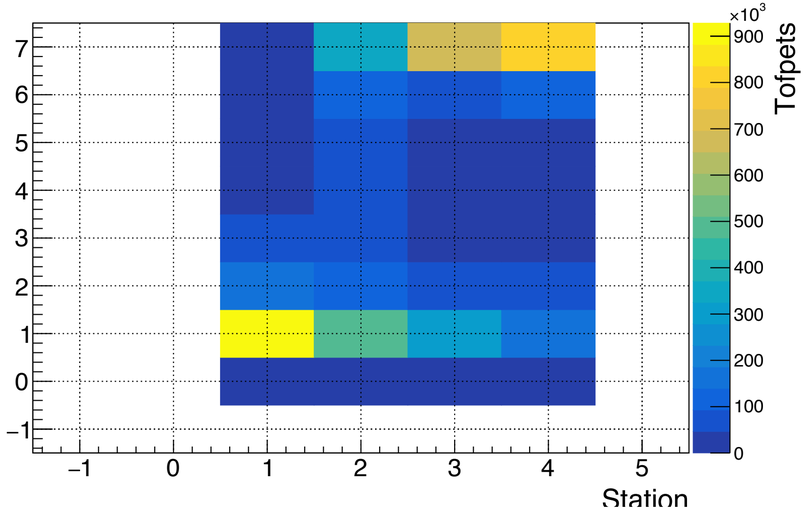
Scattering and Neutrino Detector at the LH

3 target Walls

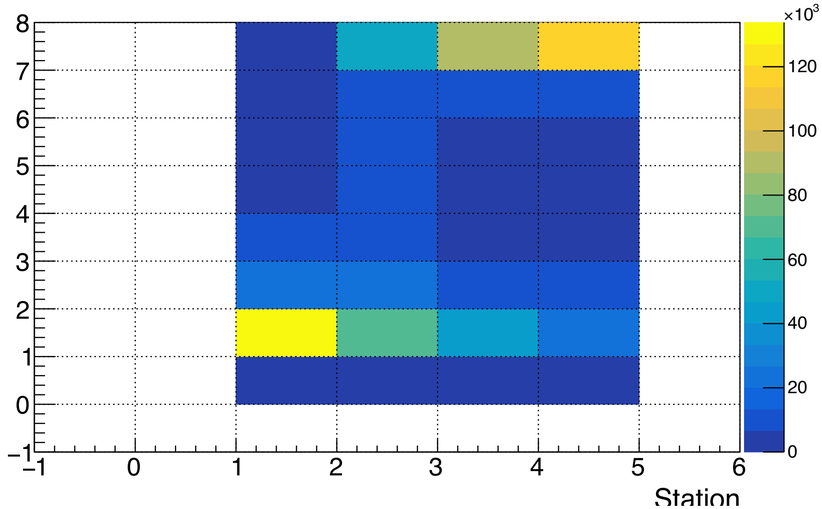
100 GeV



180 GeV



300 GeV

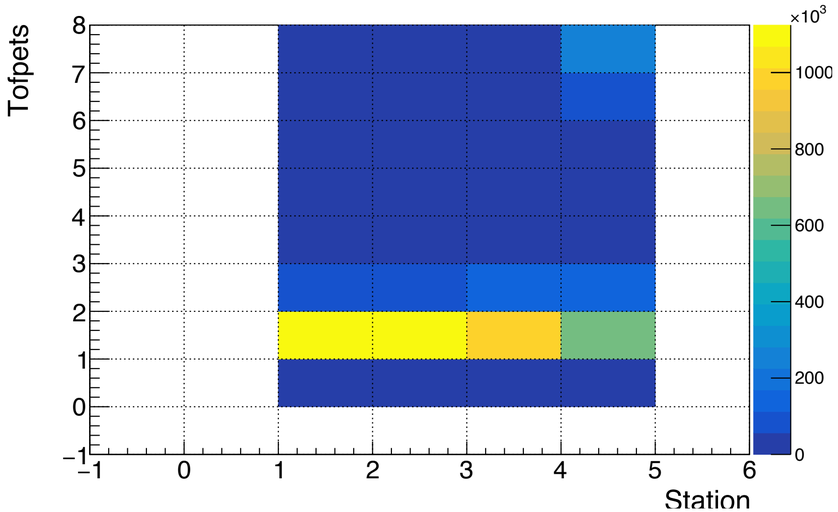


target thickness influence vs E_π

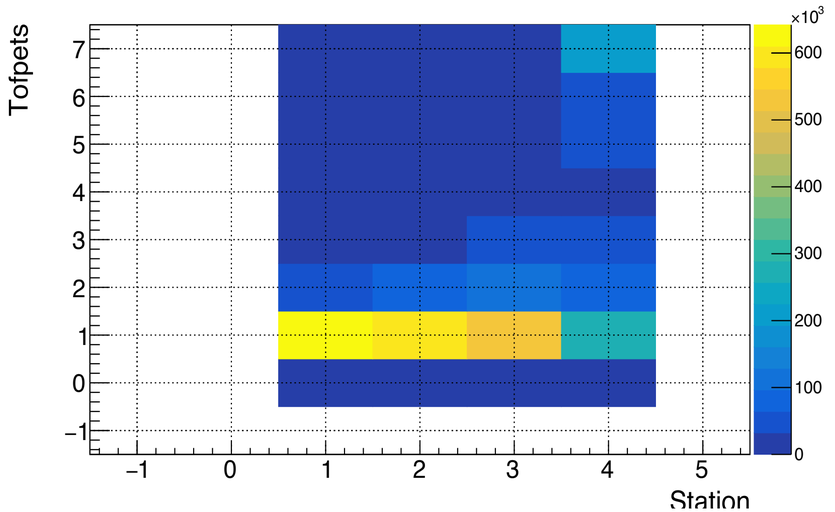
LHC
Scattering and Neutrino Detector at the LHC

1 target Wall

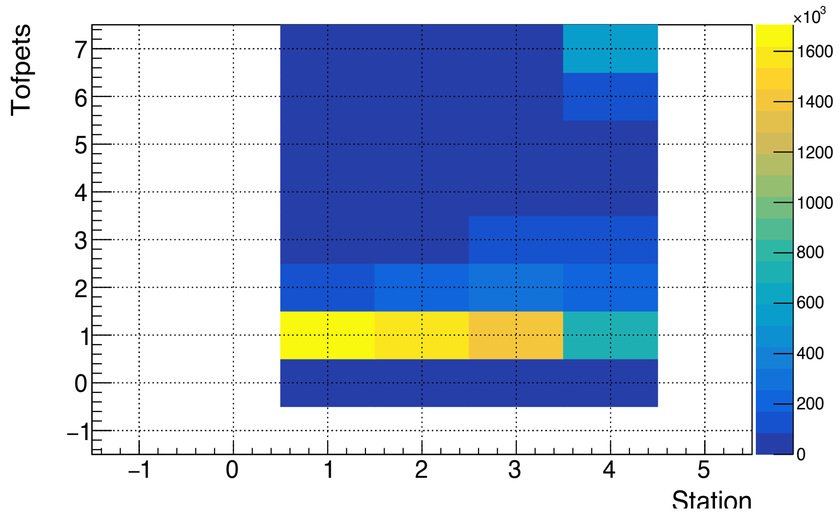
100 GeV



180 GeV



300 GeV



Impact

- Origin of showers can be precisely located with the SciFi stations
- Hadron showers spread over the entire test-beam-SciFi (13by13 cm^2) acceptance
  - Nhits/station not much useful for longitudinal shower shape
  - Difficult to extract shower centroid and width

- In TI18, SciFi stations are 39by39 cm^2, and λint in W = 11.3 cm, even so the accuracy of shower centroid and width would be coarse, since a large part will be “flat”
- In electron neutrino events, separation of the EM shower (R_M~1-2 cm) from the hadronic shower would be challenging

Possible Strategy

- for now, use SciFi to localize the shower origin, and rely solely on US stations to parametrize the shower parameters
    - centroid and width (mainly US1,US2)
    - depth
    - integral charge content

  as function of pion energy and interaction depth

- meanwhile, assess whether the amplitude information of SciFi SiPMs signals can be used
    - Very low light yield on MIPs, but how about showers?

ISSUE: SciFi: tofpet multiplicity per station

π fly through probability		
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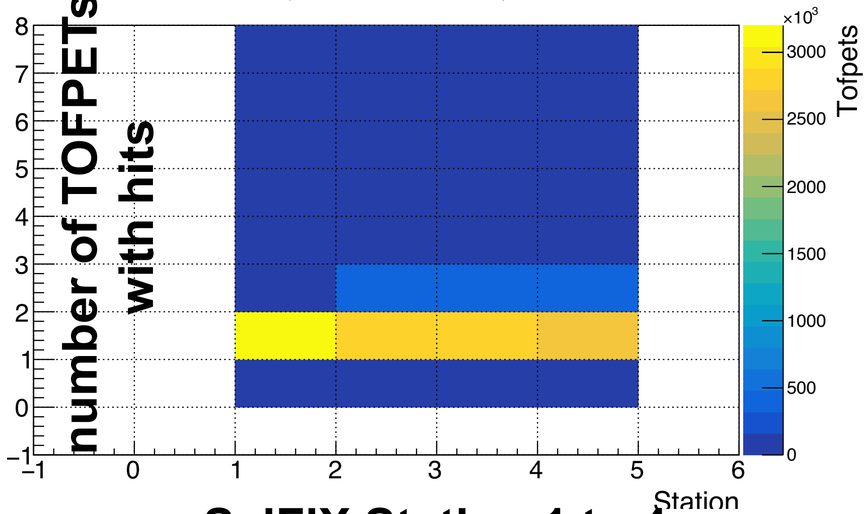
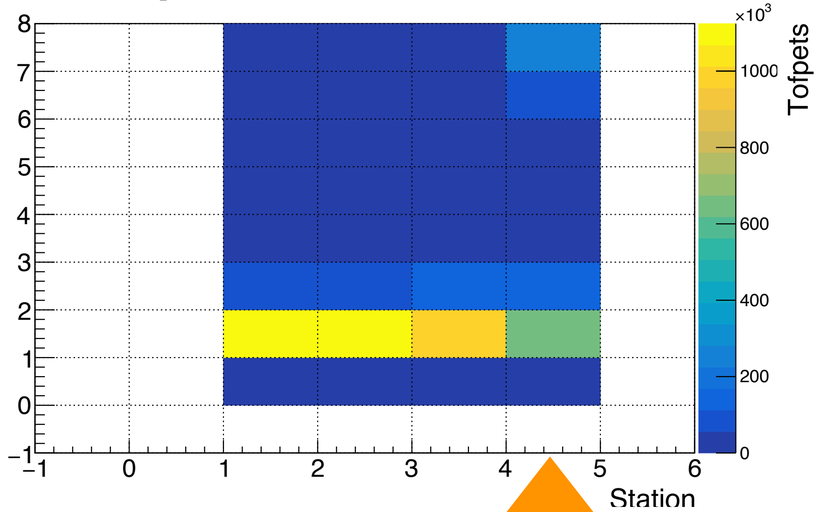
SciFiX planes; similarly for SciFiY

muon, 160 GeV, 3 walls

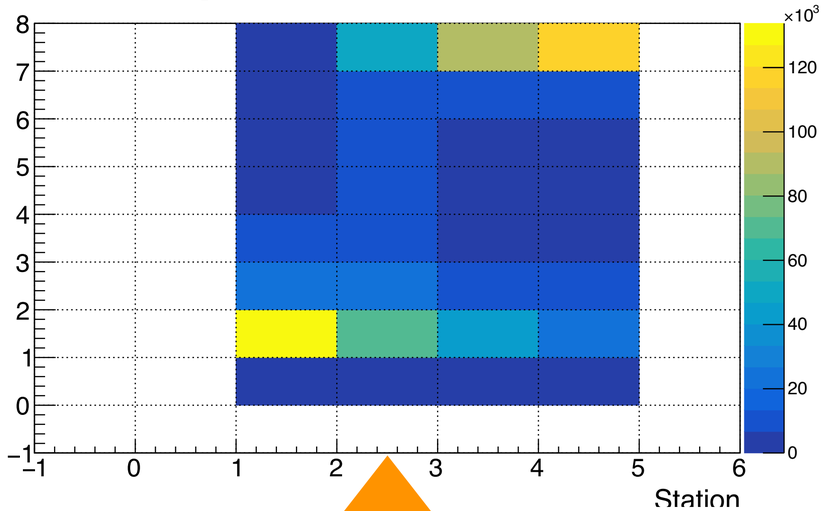


SciFiX Station 1 to 4

pion, 100 GeV, 1 wall



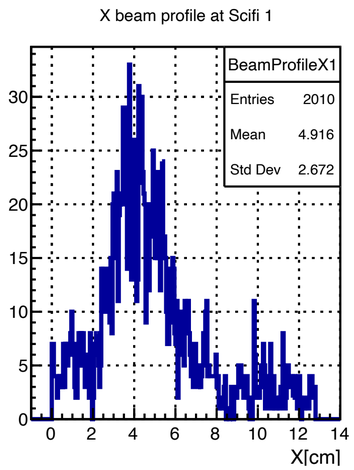
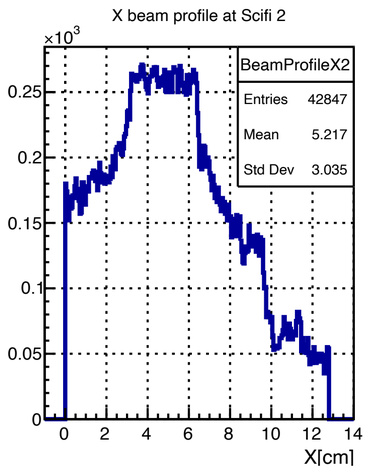
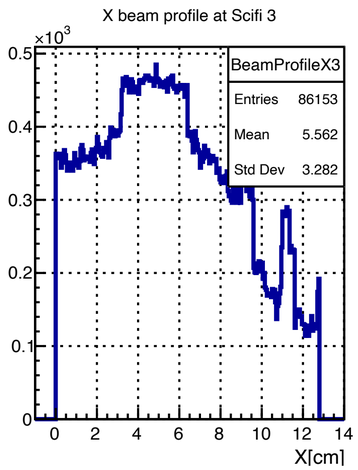
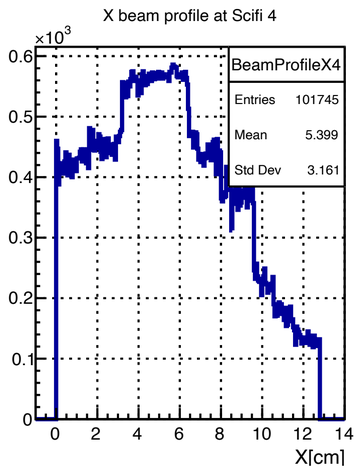
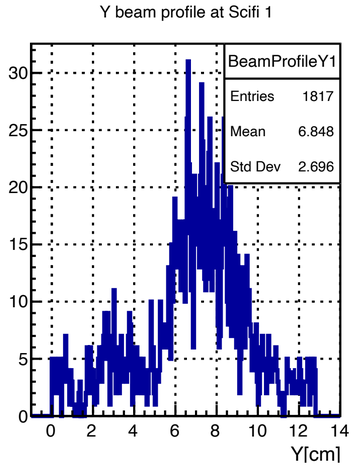
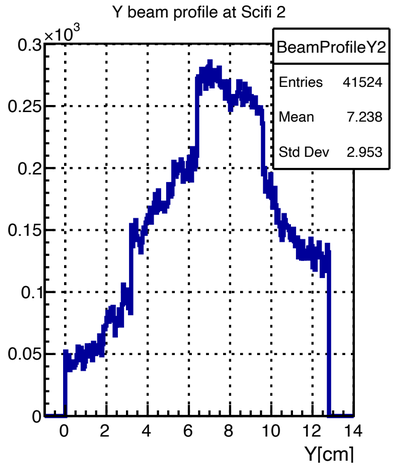
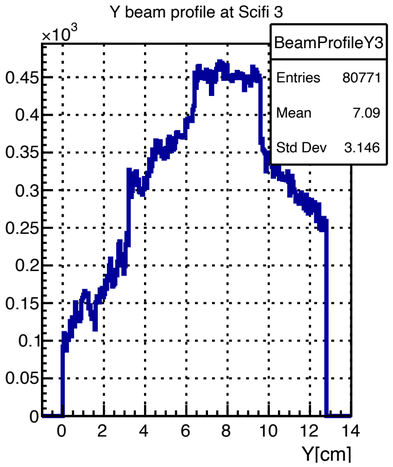
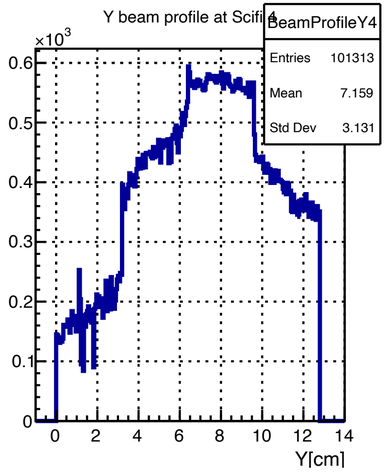
pion, 300 GeV, 3 wall



From their early development,

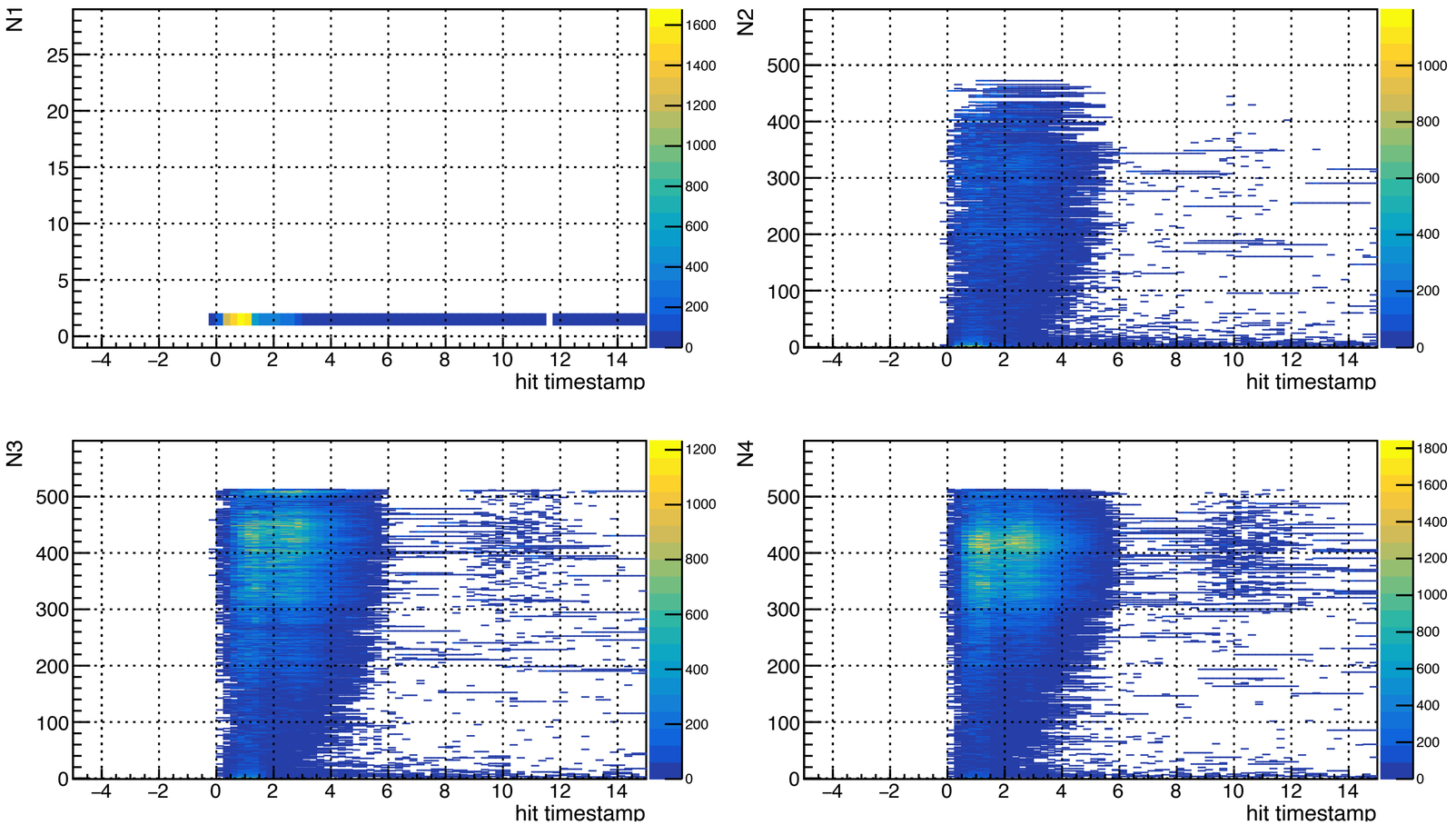
showers spread over the entire test-beam-SciFi acceptance, i.e. 8 TOPETs

SF hit distribution in X and Y per station

	SF1	2	3	4
X				
Y				

300 GeV
3 Twalls

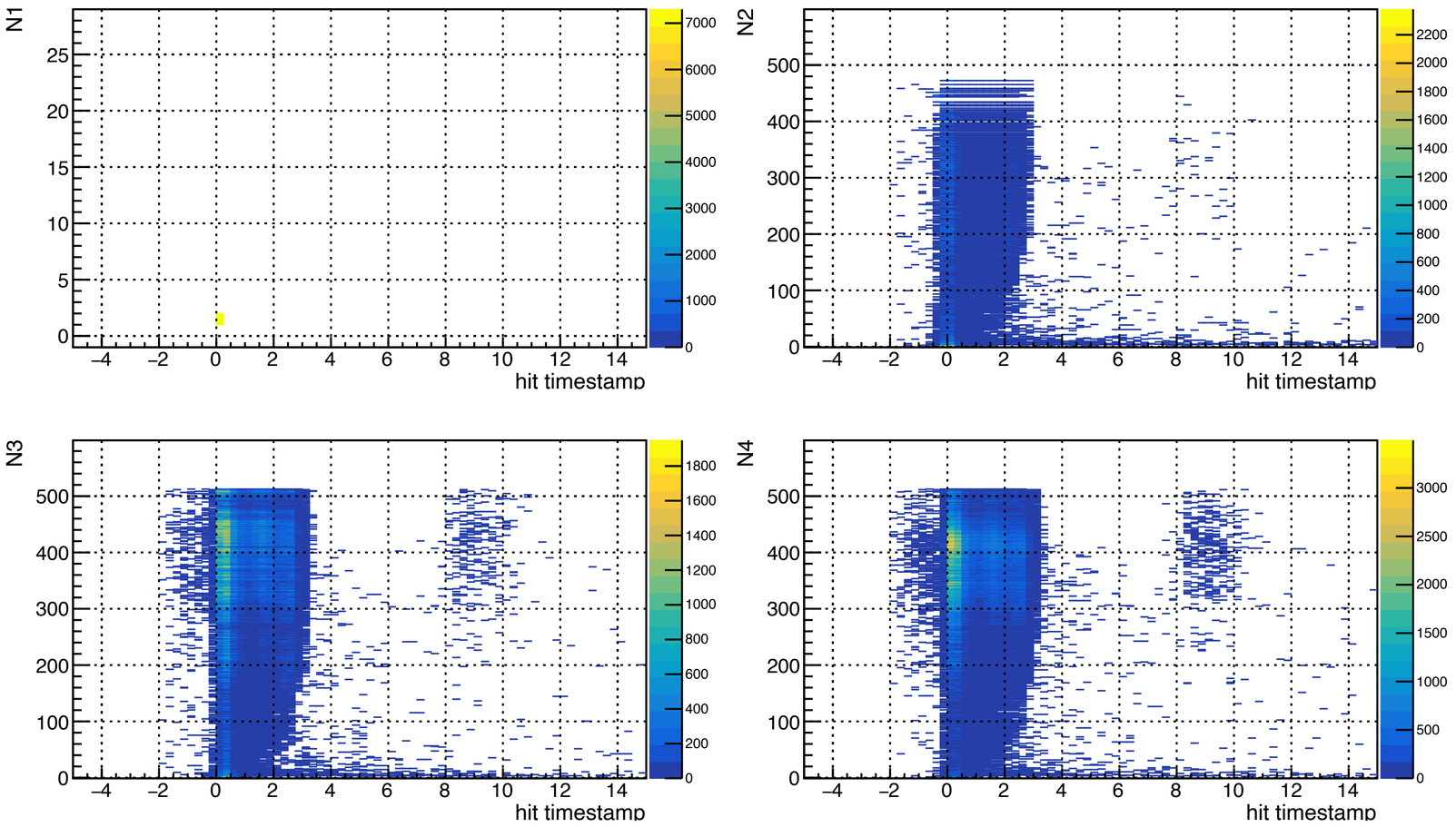
SF hit timestamps per station



300 GeV
3 walls

— 1 hit in both SciFi1 X and Y

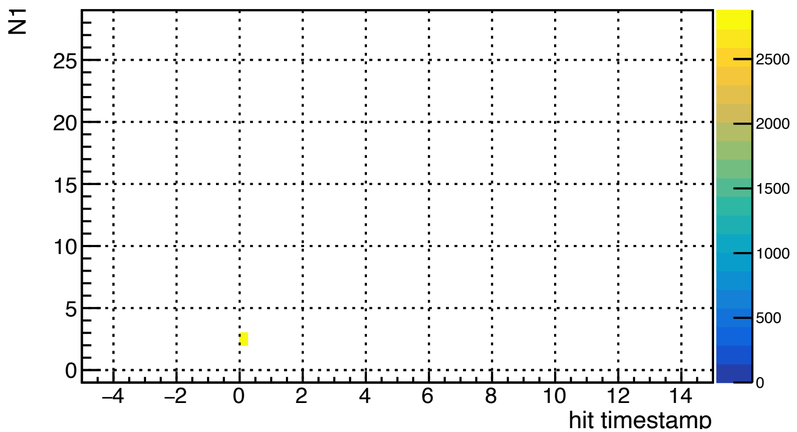
SF hit timestamps relative to SF1

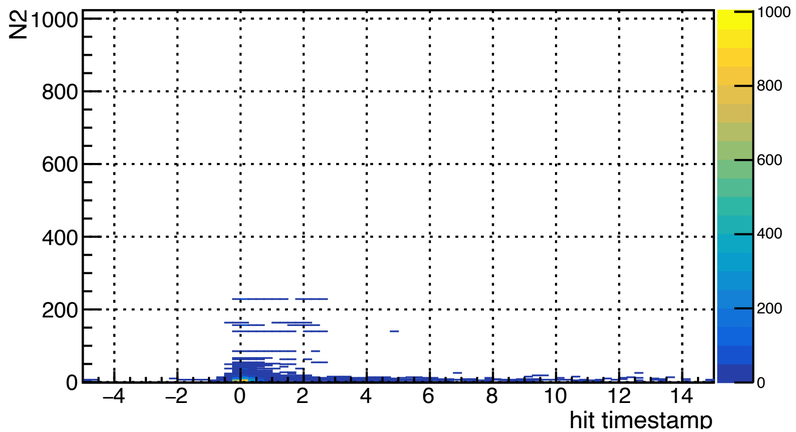


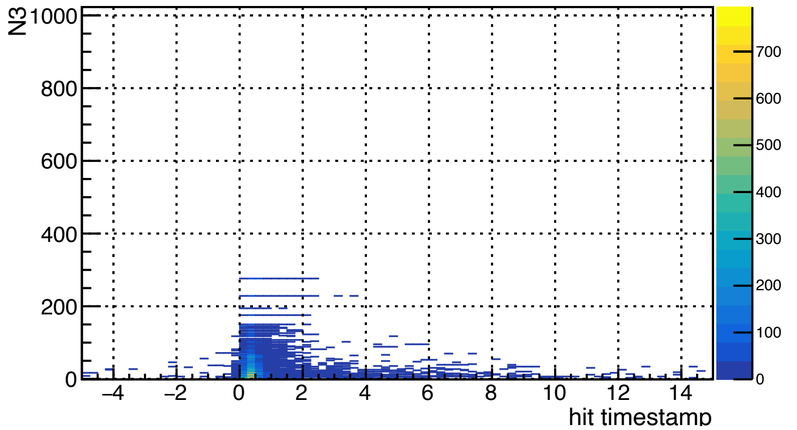
300 GeV
3 walls

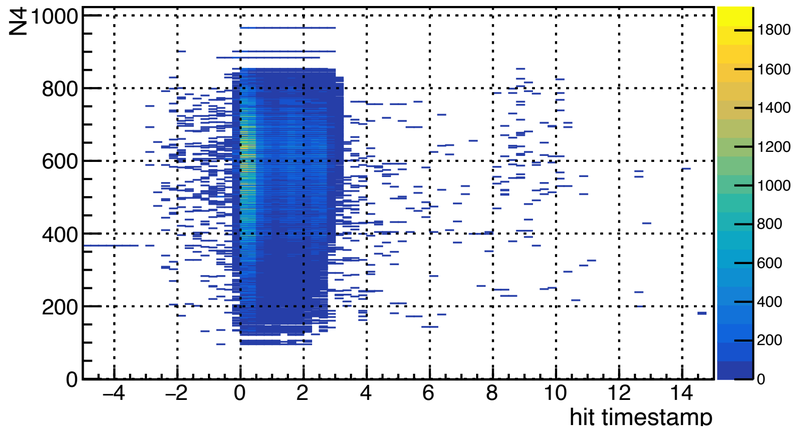
— 1 hit in both SciFi1 X and Y
— in 3<X<10, 3<Y<10
— hit timestamps relative to SciFi1

“afterglow”





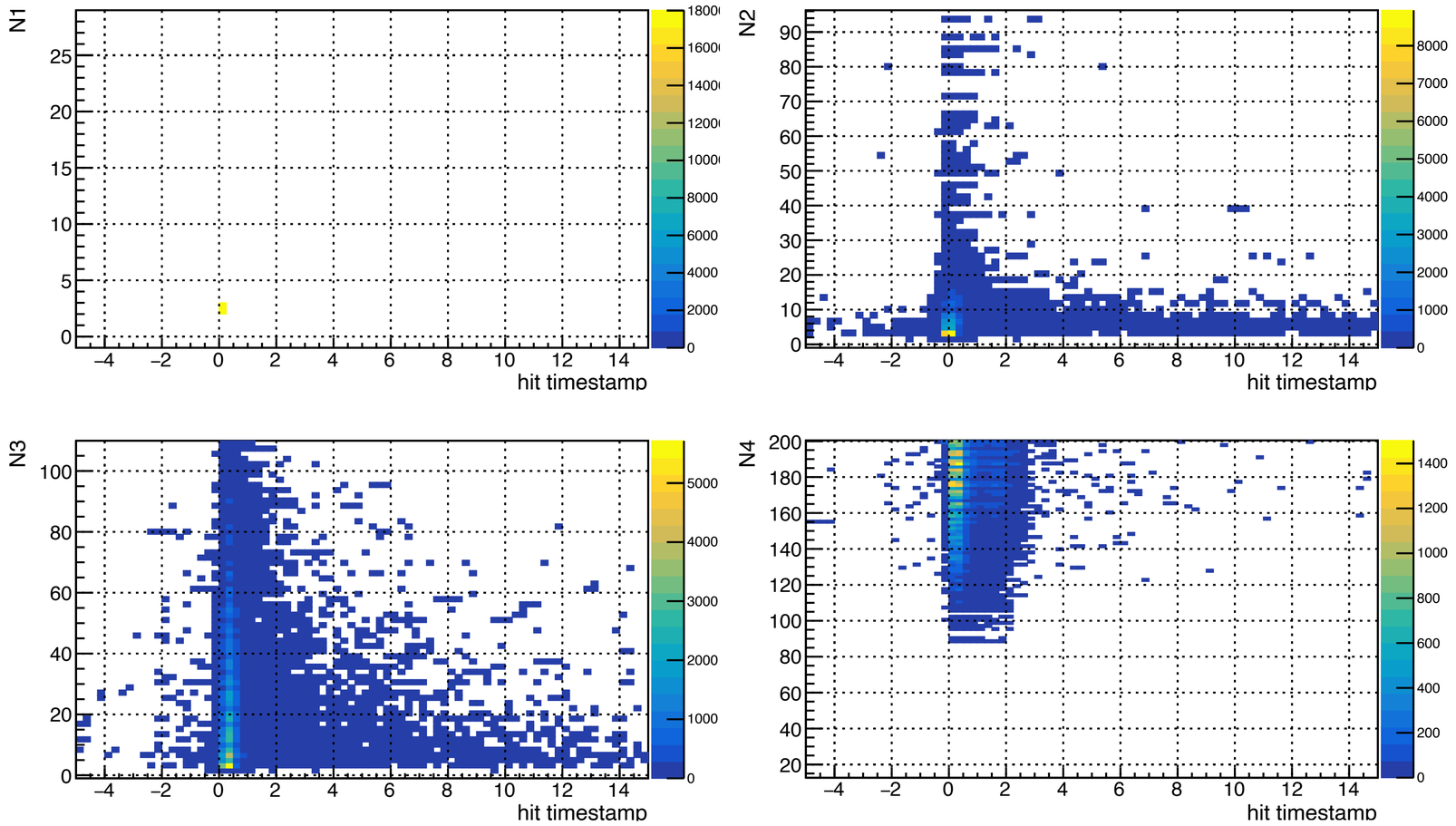




180 GeV
1 Twall

— 1 hit in both SciFi1 X and Y
— in 3<X<10, 3<Y<10
— hit timestamps relative to SciFi1

“afterglow” and hit multiplicity

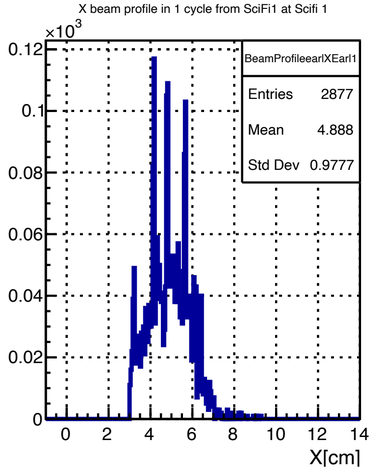


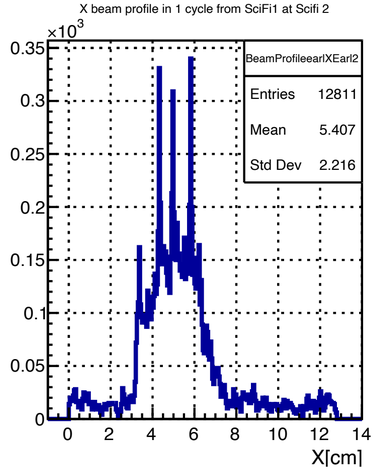
180 GeV
1 Twall

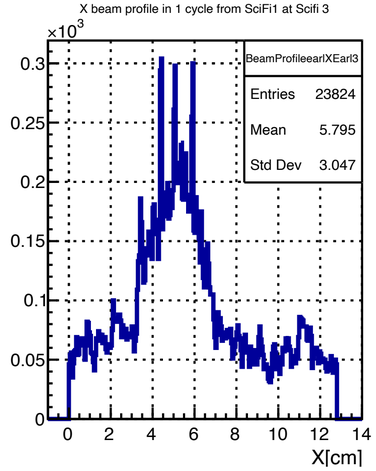
ZOOM IN

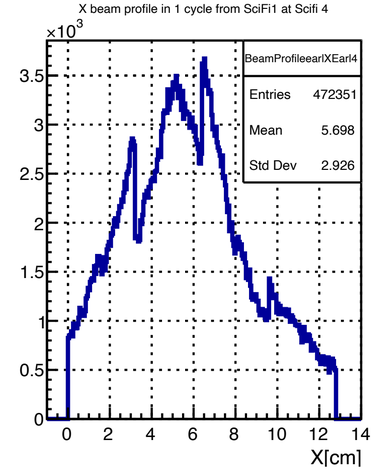
“afterglow” effect only when large hit multiplicity

SF hit distribution in X per station



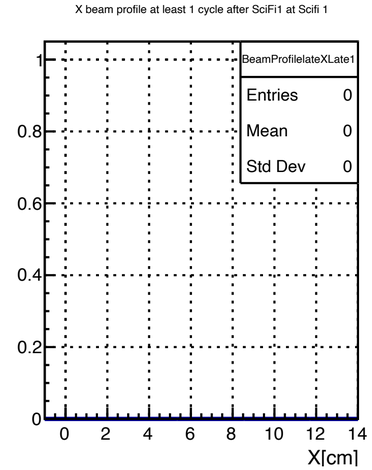


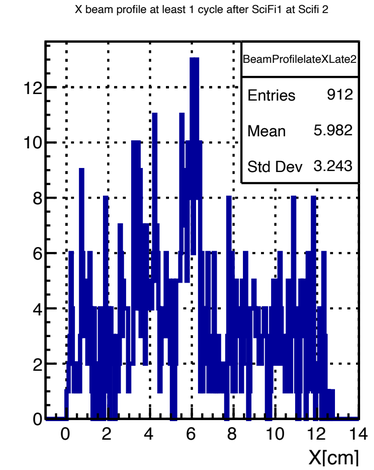


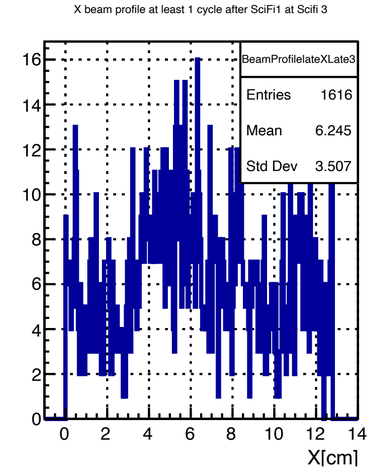


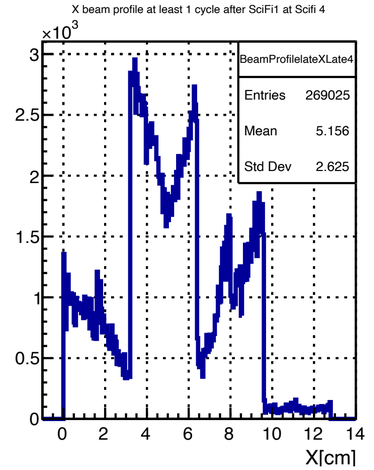
hits within 1 clock cycle (6.25 ns)

hit timestamps relative to SciFi1 X (similarly for Y)









hits later than 1 clock cycle (6.25 ns)

“afterglow” hits are spurious

SF “in-time” hits in X and Y per station

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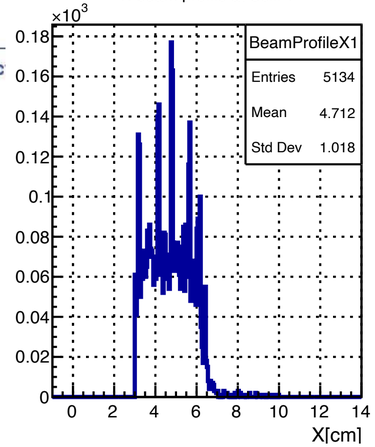
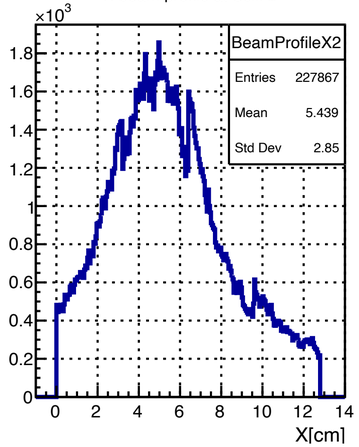
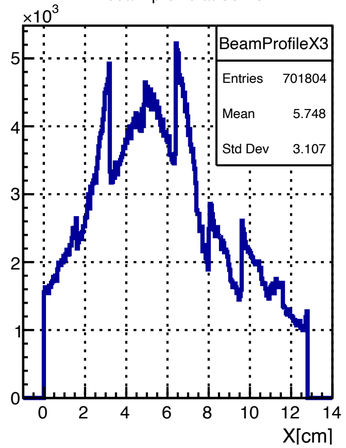
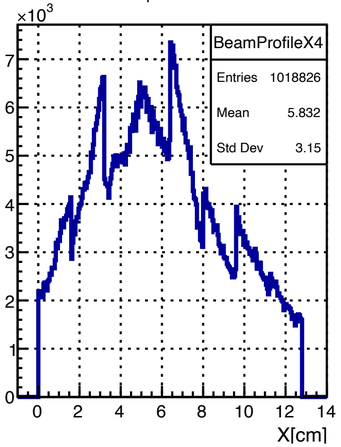
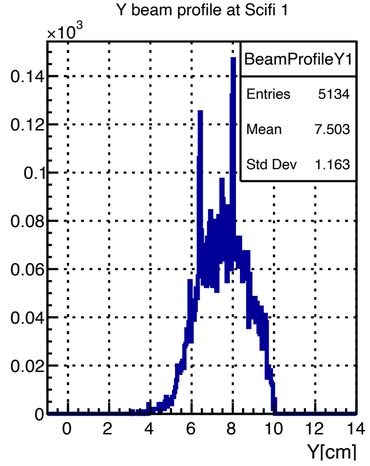
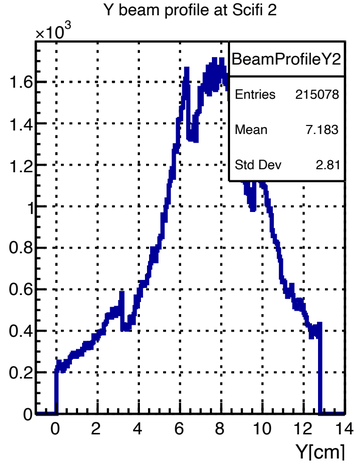
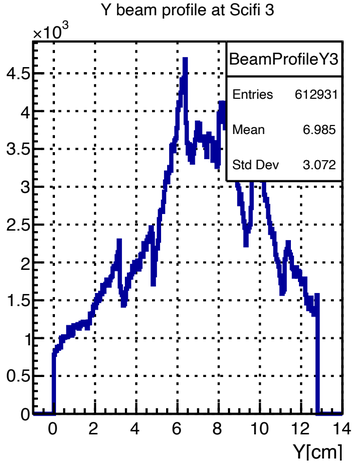
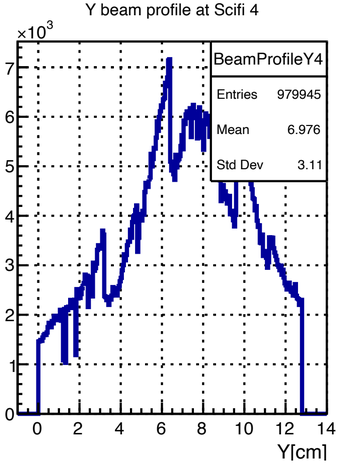
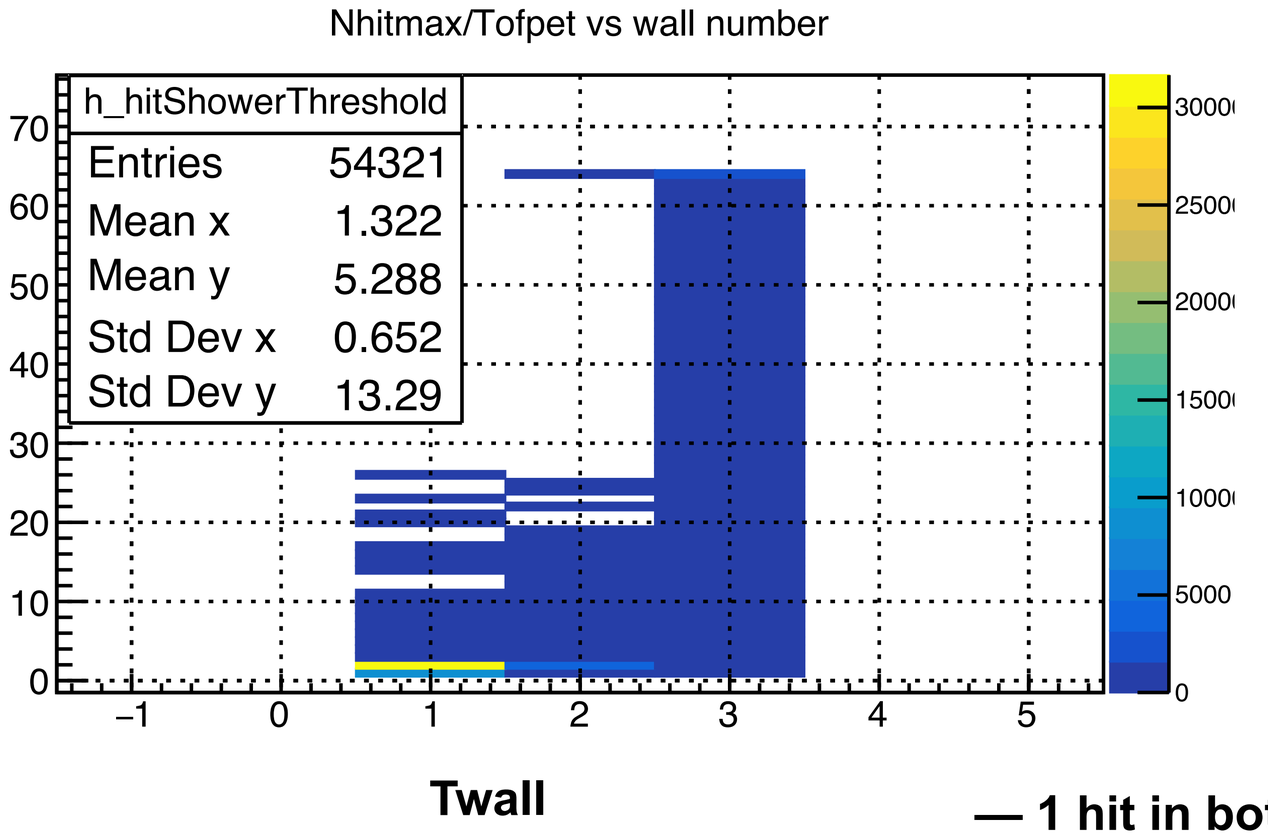
X				
Y				

300 GeV
3 walls

— 1 hit in both SciFi1 X and Y
— in 3<X<10, 3<Y<10
— hit timestamps within 1 ckcycle to SciFi1

TOFPET occupancy

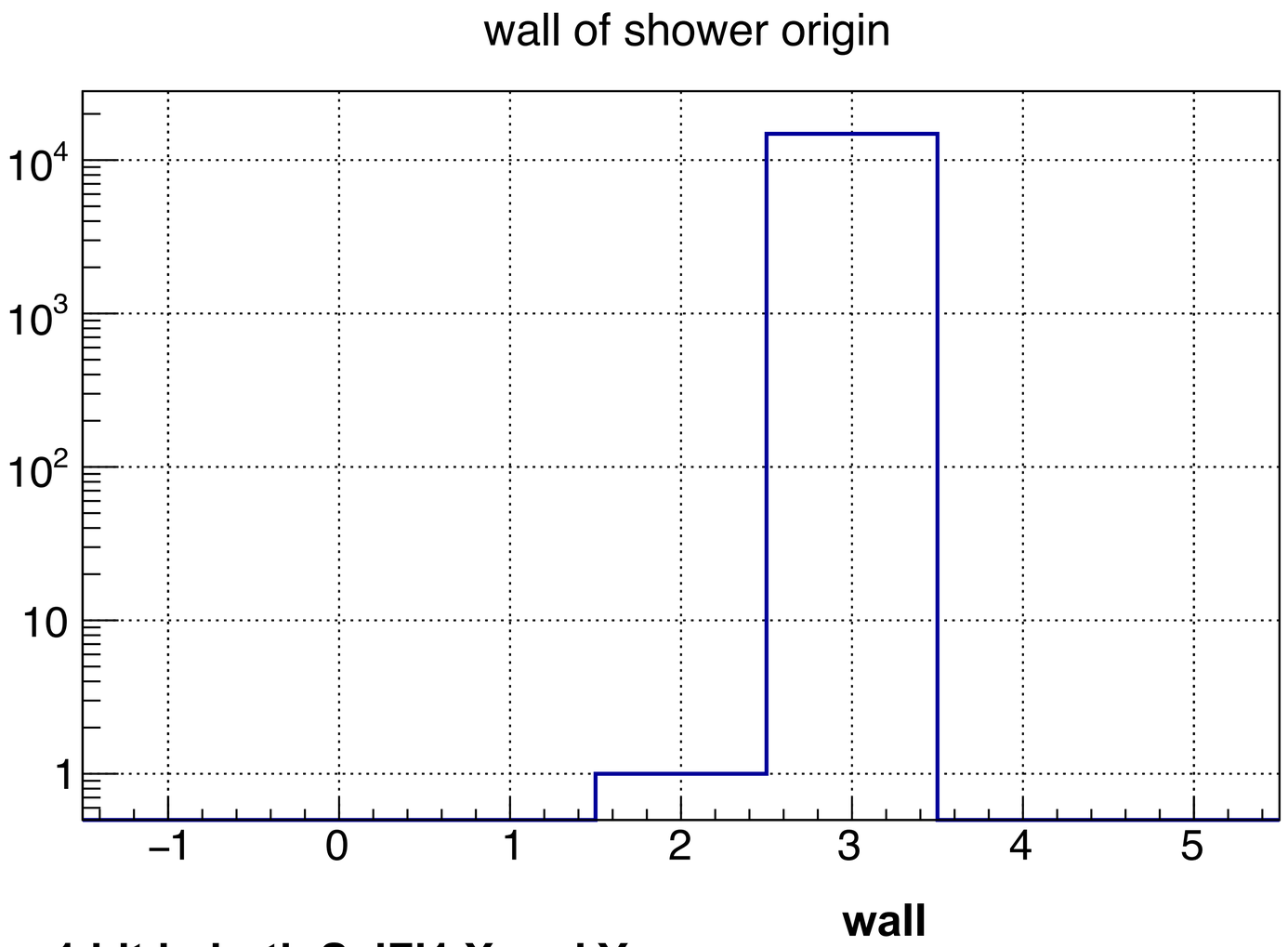
Nhit/tofpet



180 GeV
1 Twall

— 1 hit in both SciFi1 X and Y
— in 3<X<10, 3<Y<10
— hit timestamps within 1 ckcycle to SciFi1

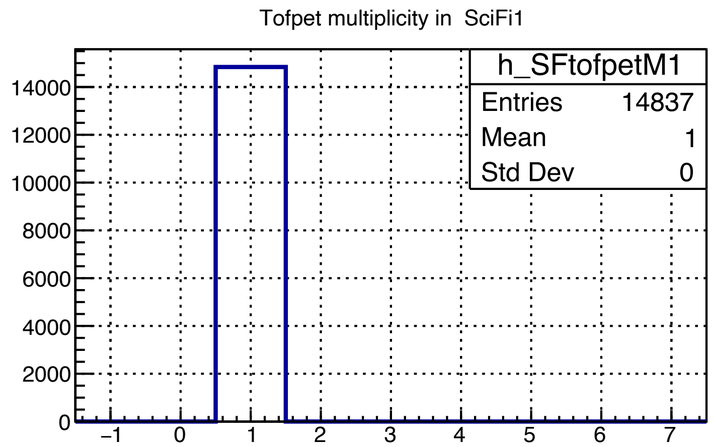
Shower origin tag

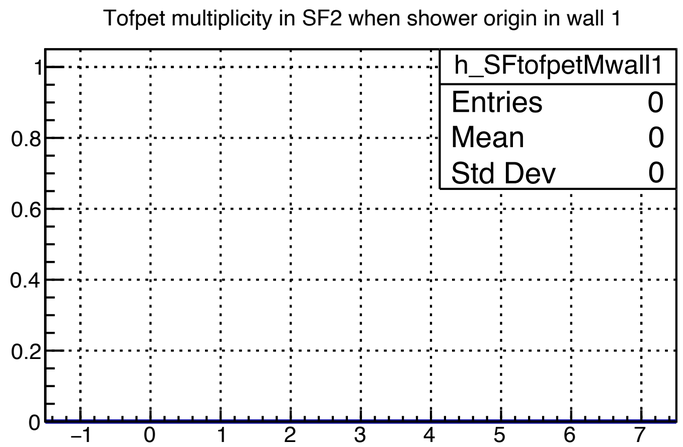


180 GeV
1 Twall

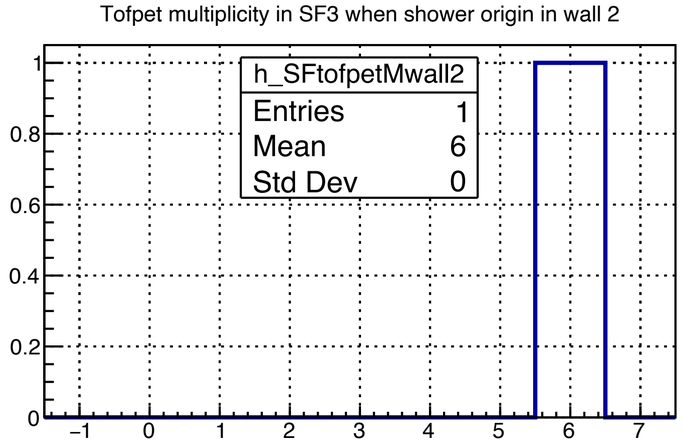
— 1 hit in both SciFi1 X and Y
— in 3<X<10, 3<Y<10
— hit timestamps within 1 ckcycle to SciFi1
— shower origin= first wall that has >30 SciFi hits in one tofpet both in X and in Y

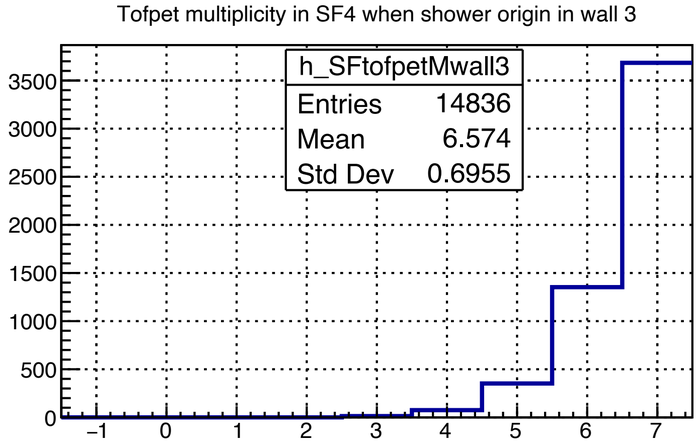
TOFPET multiplicity vs shower origin





180 GeV
1 Twall

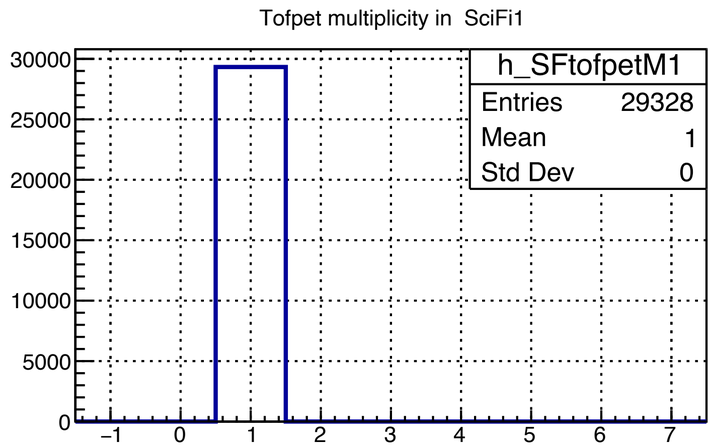


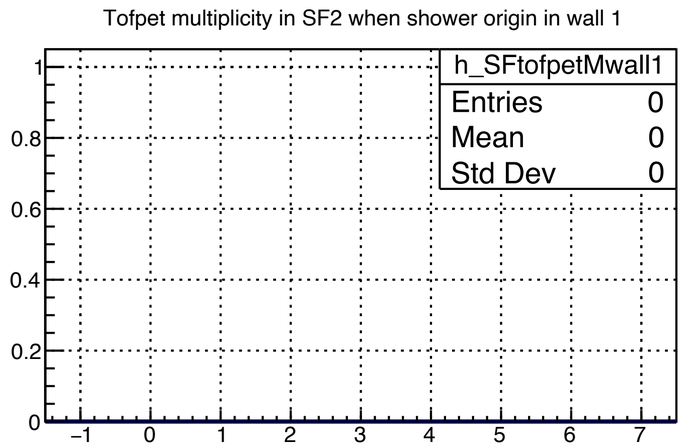


number of firing TOFPETs

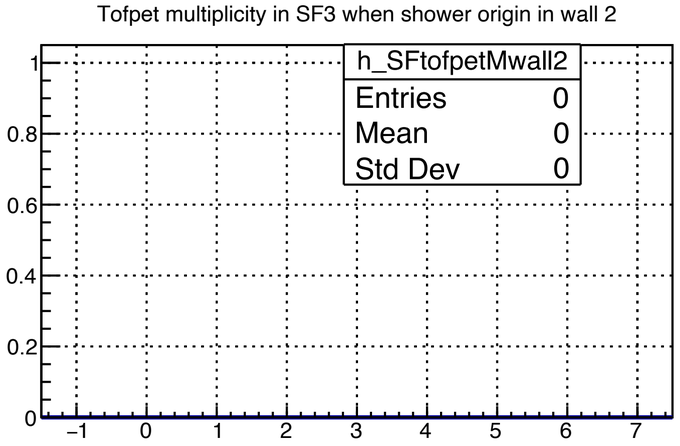
— 1 hit in both SciFi1 X and Y
— in 3<X<10, 3<Y<10
— hit timestamps within 1 ckcycle to SciFi1
— shower origin= first wall that has >30 SciFi hits in one tofpet both in X and in Y

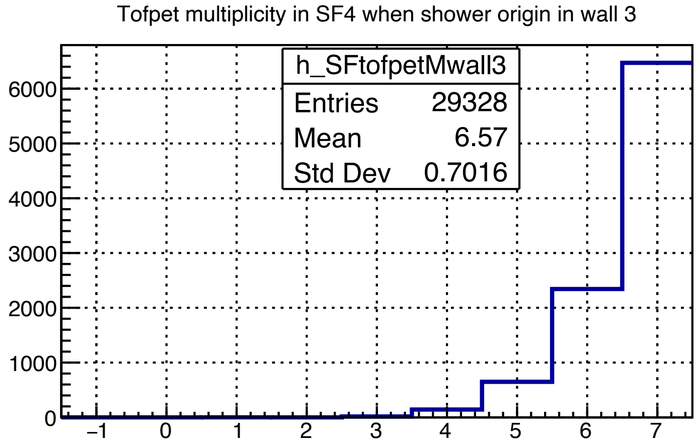
TOFPET multiplicity vs shower origin





300 GeV
1 Twall





number of firing TOFPETs

— 1 hit in both SciFi1 X and Y
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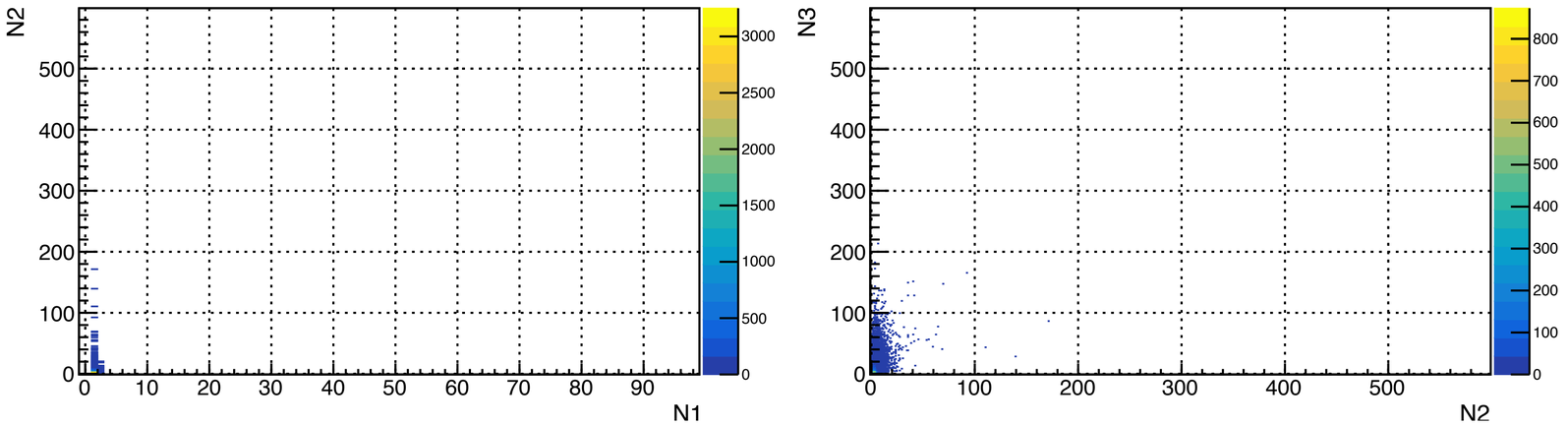
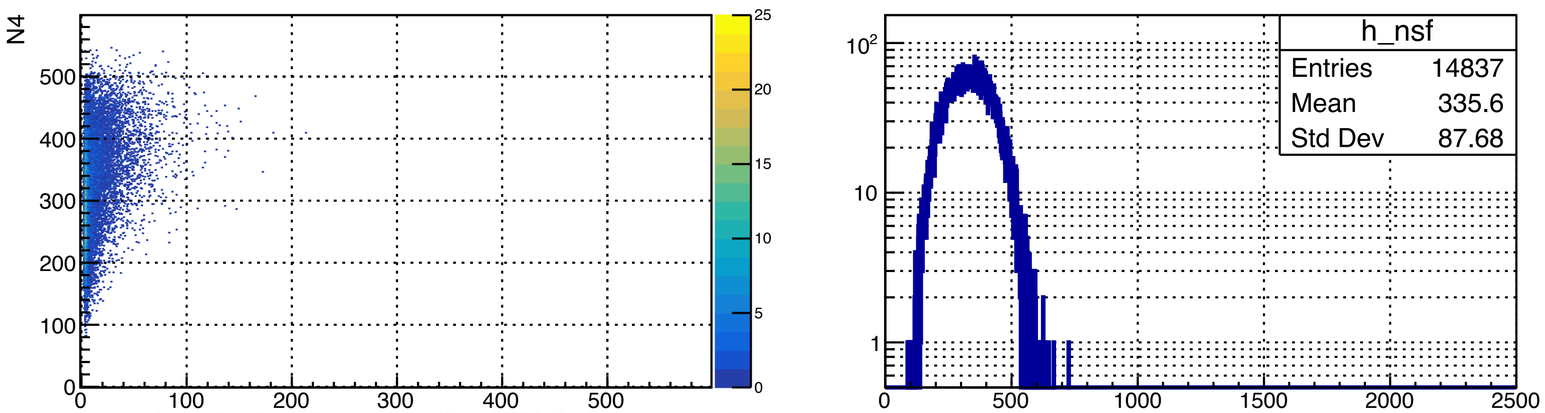
— hit timestamps within 1 ckcycle to SciFi1
— shower origin= first wall that has >30 SciFi hits in one tofpet both in X and in Y

SF hits 180GeV

180 GeV
1 Twall

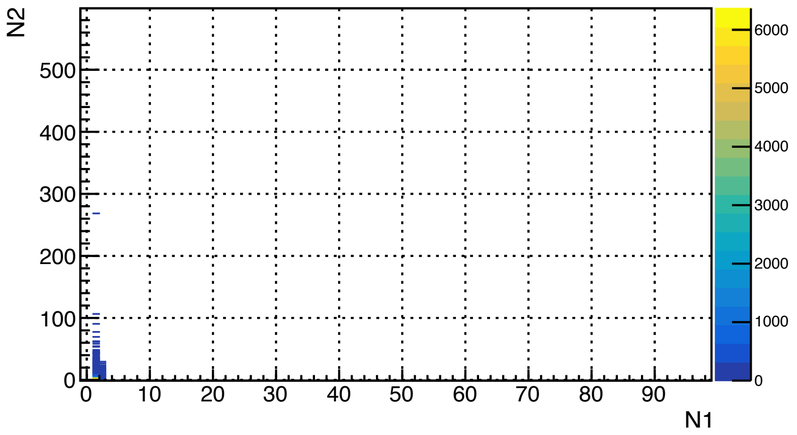


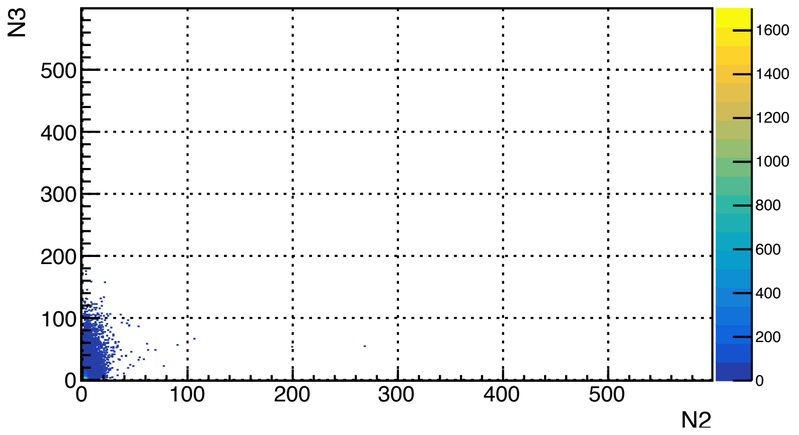


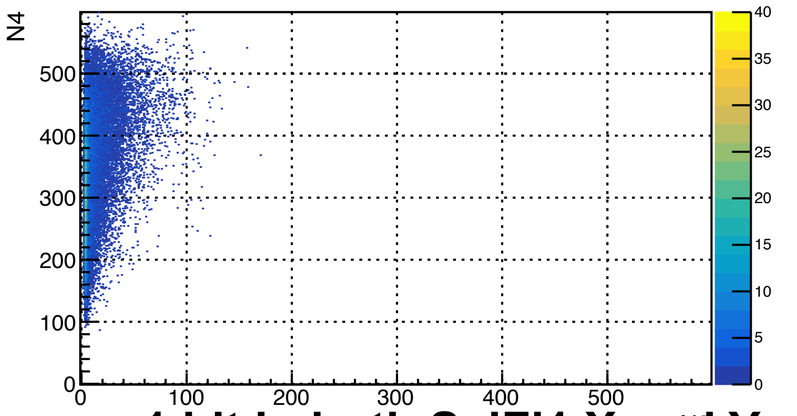
— 1 hit in both SciFi1 X and Y
— in 3<X<10, 3<Y<10
— hit timestamps within 1 ckcycle to SciFi1
— shower origin= first wall that has >30 SciFi hits in one tofpet both in X and in Y

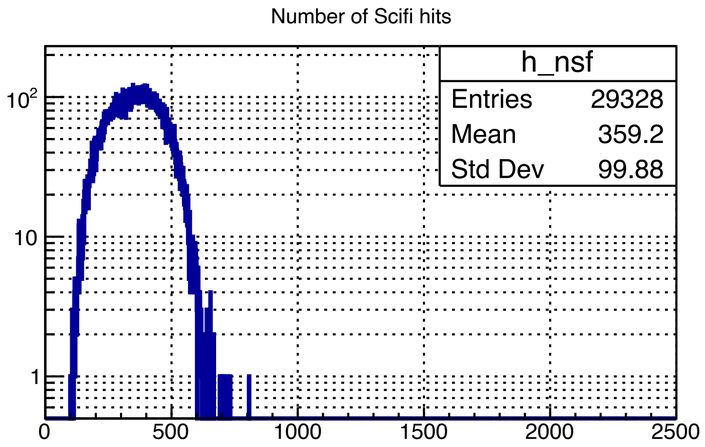
SF hits 300 GeV

300 GeV
1 Twall



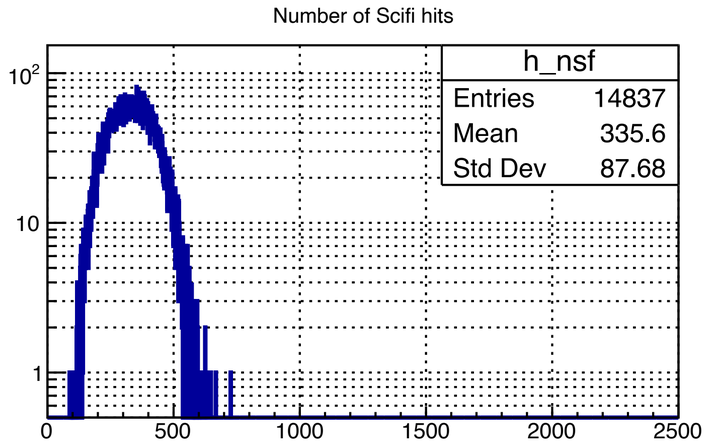


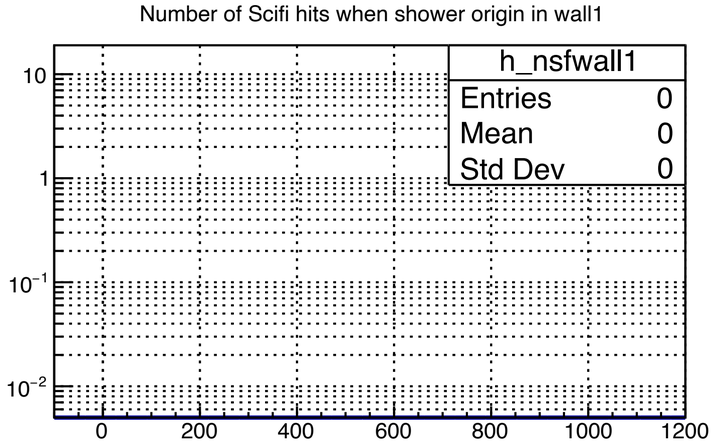


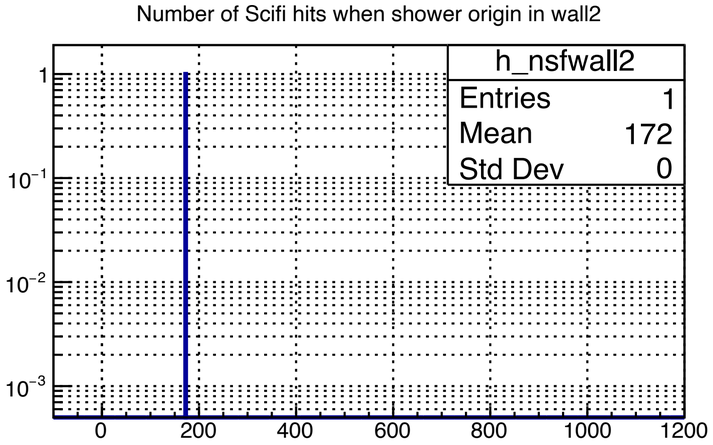


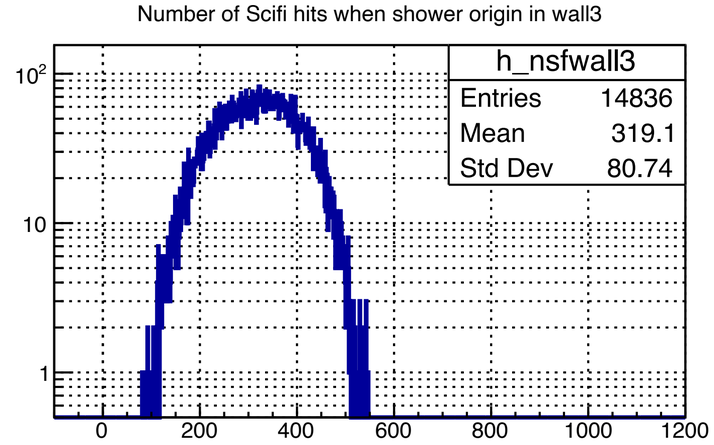
— 1 hit in both SciFi1 X and Y
— in 3<X<10, 3<Y<10
— hit timestamps within 1 ckcycle to SciFi1
— shower origin= first wall that has >30 SciFi hits in one tofpet both in X and in Y

SF hits per shower origin, 180 GeV





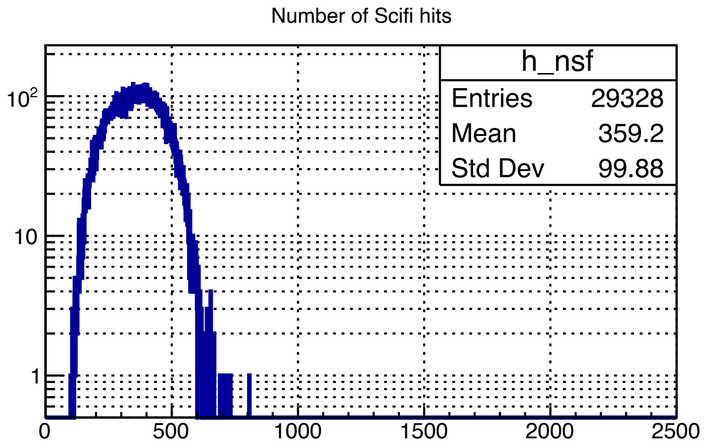


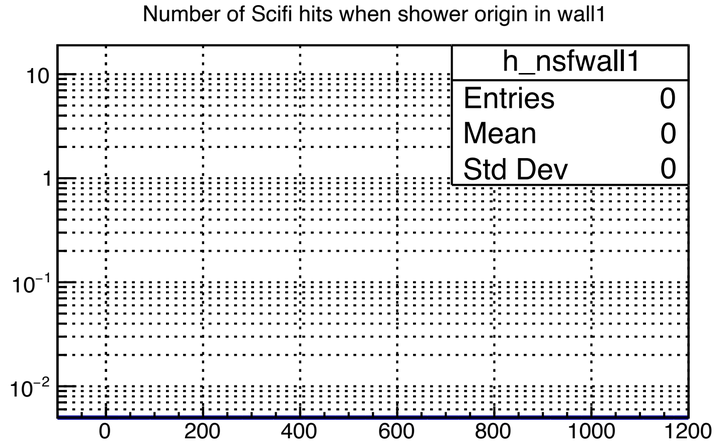


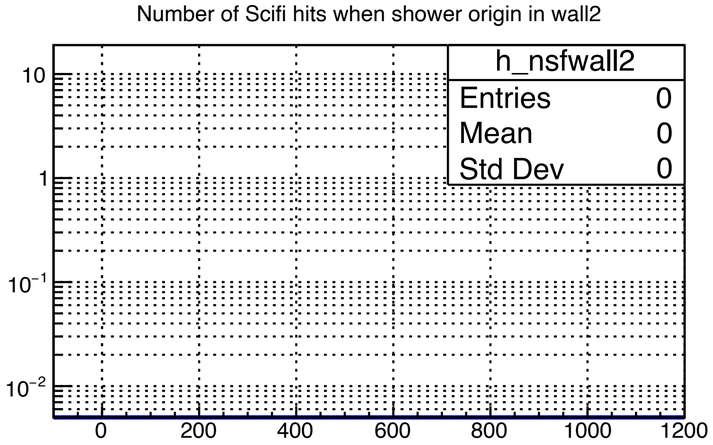
180 GeV
1 Twall

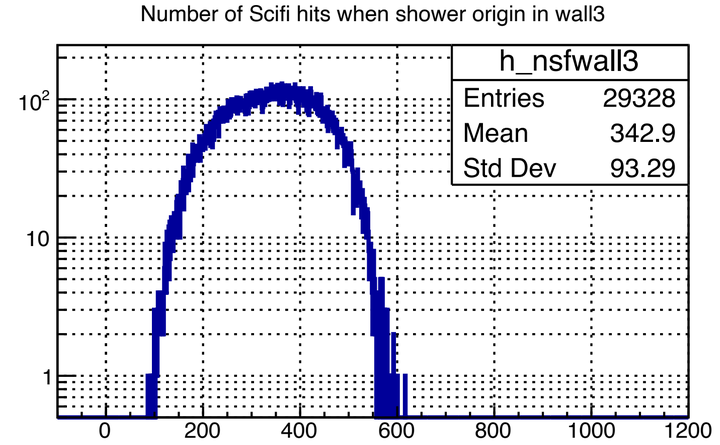
— 1 hit in both SciFi1 X and Y
— in 3<X<10, 3<Y<10
— hit timestamps within 1 ckcycle to SciFi1
— shower origin= first wall that has >30 SciFi hits in one tofpet both in X and in Y

SF hits per shower origin, 300 GeV









300 GeV
1 Twall

— 1 hit in both SciFi1 X and Y
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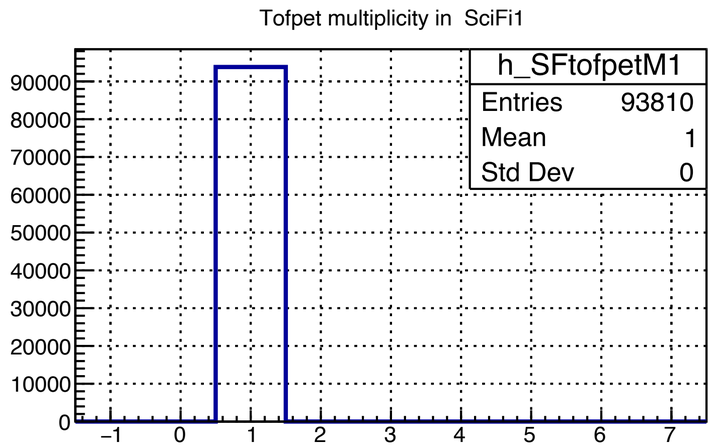
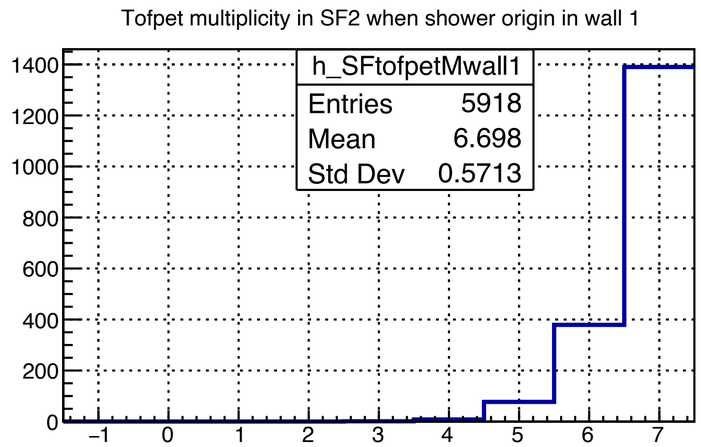
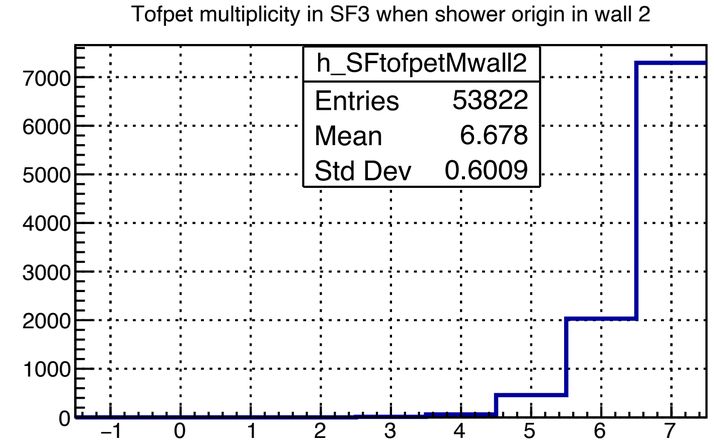
— hit timestamps within 1 ckcycle to SciFi1
— shower origin= first wall that has >30 SciFi hits in one tofpet both in X and in Y

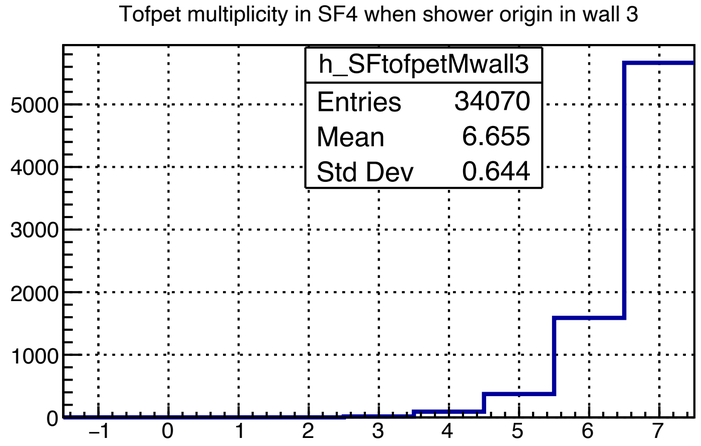
TOFPET multiplicity vs shower origin, 3 walls





300 GeV
3 Twall





number of firing TOFPETs

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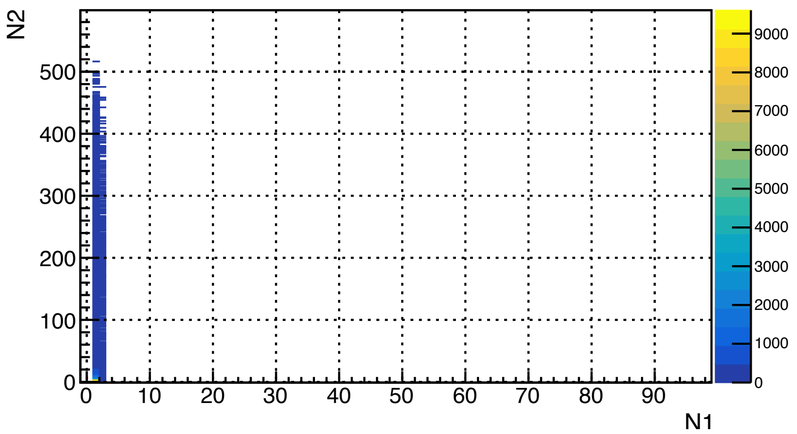
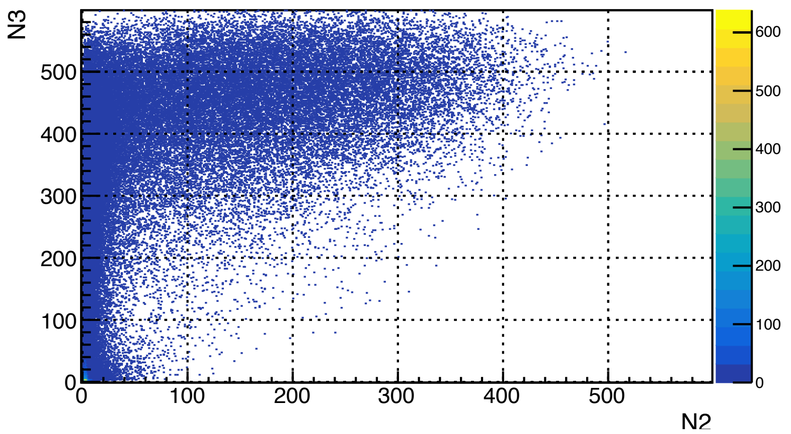
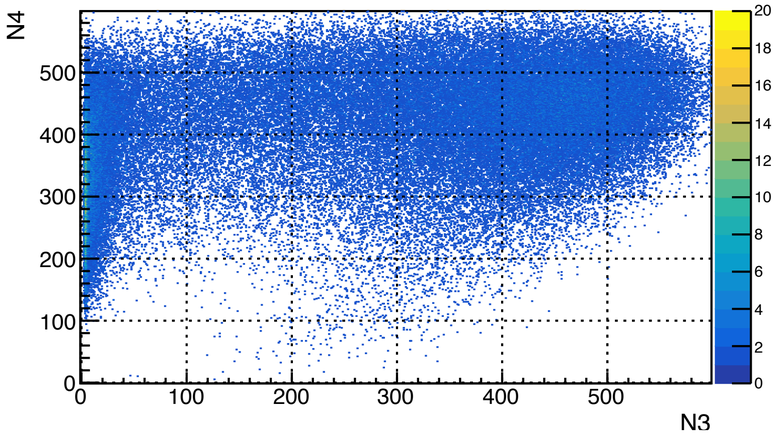
— shower origin= first wall that has >30 SciFi hits in one tofpet both in X and in Y

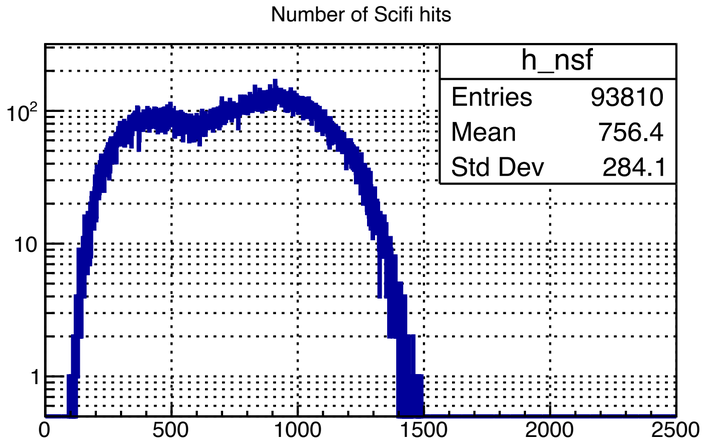
SF hits 300 GeV, 3 Target walls





300 GeV
3 Twall





— 1 hit in both SciFi1 X and Y
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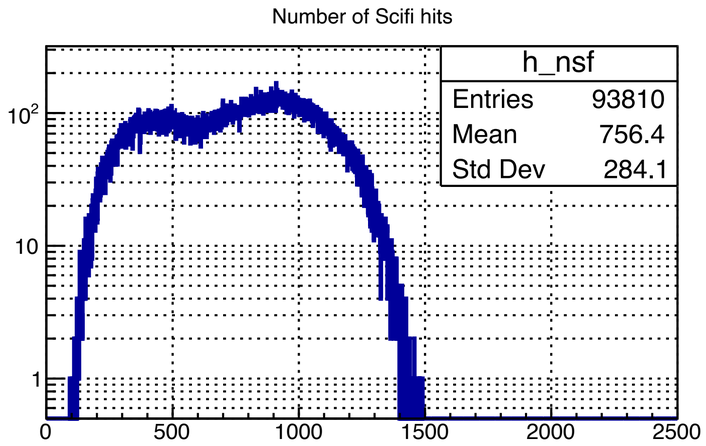
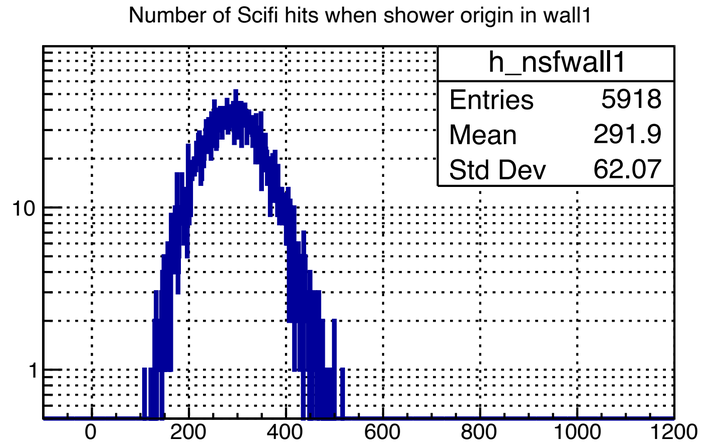
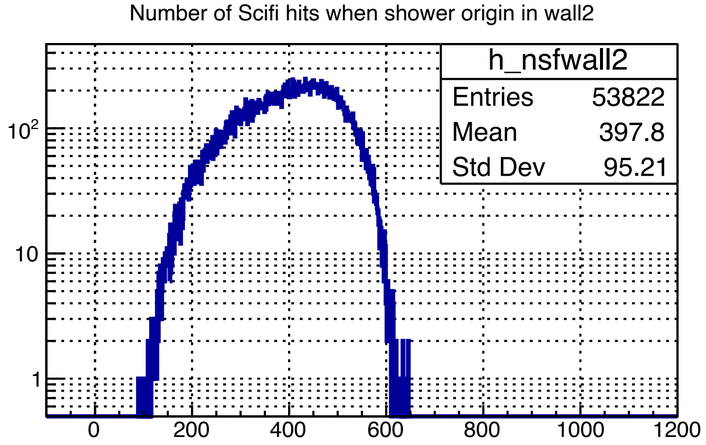
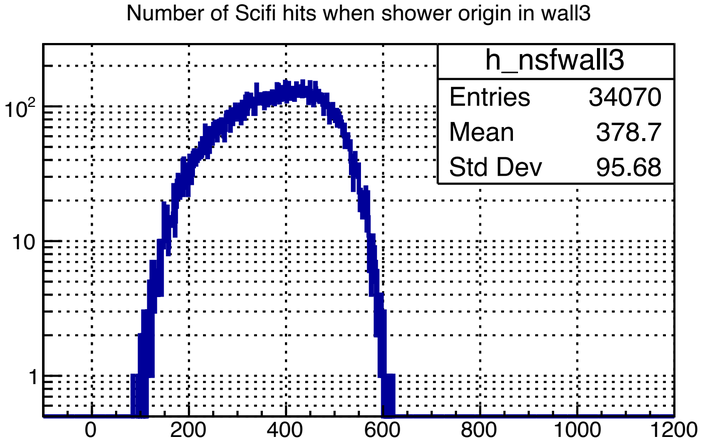
SF hits 300 GeV per shower origin , 3 Target walls









300 GeV
3 Twall

— 1 hit in both SciFi1 X and Y
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— hit timestamps within 1 ckcycle to SciFi1
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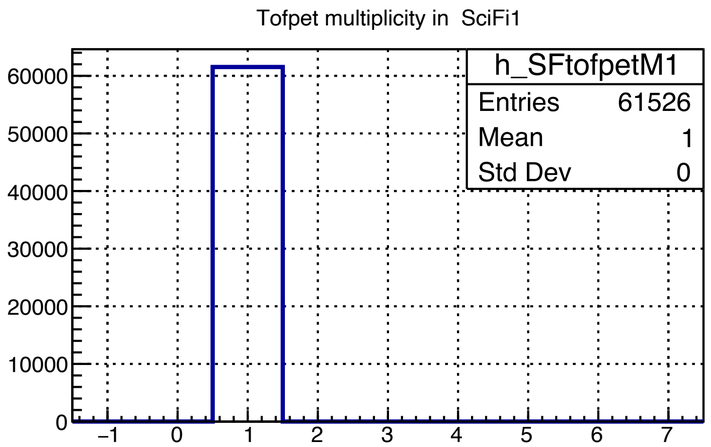
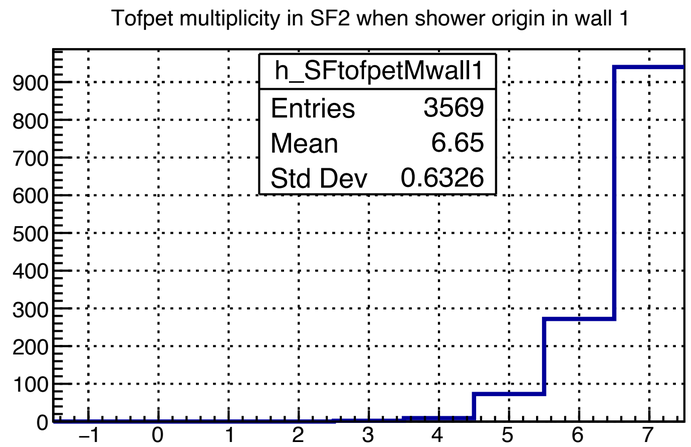
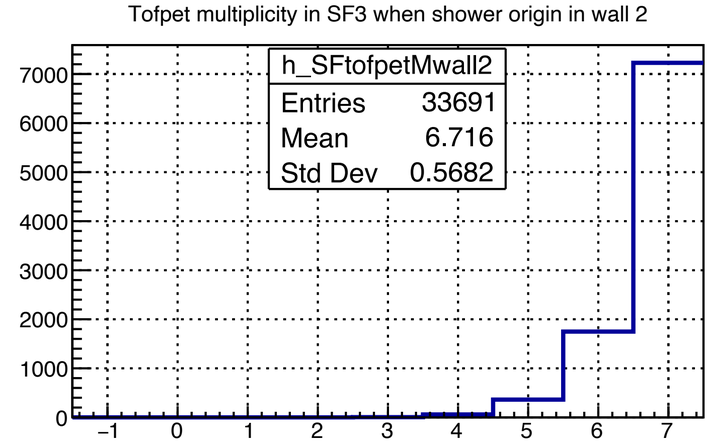
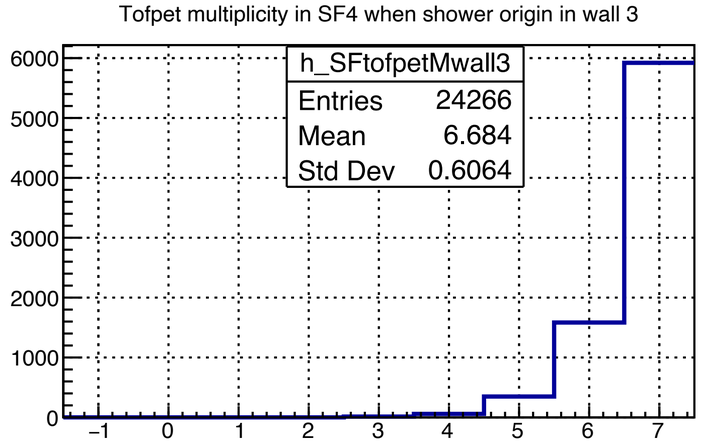
TOFPET multiplicity vs shower origin, 3 walls





100 GeV
3 Twall





number of firing TOFPETs

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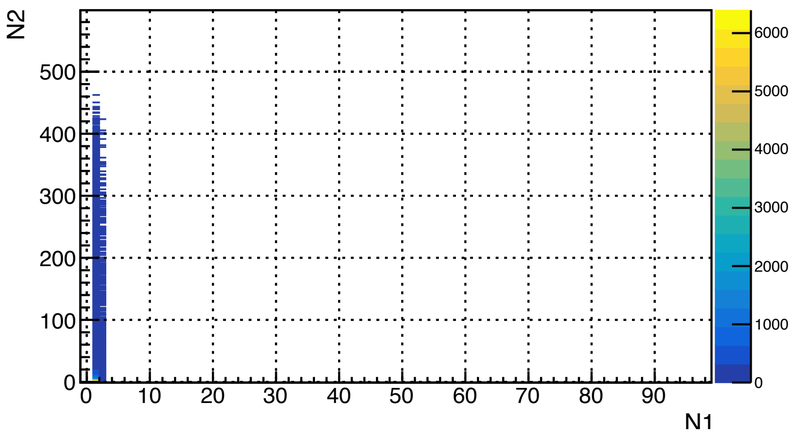
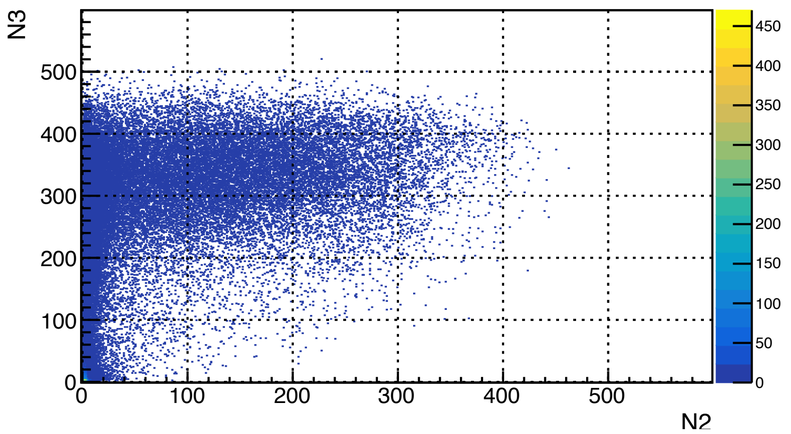
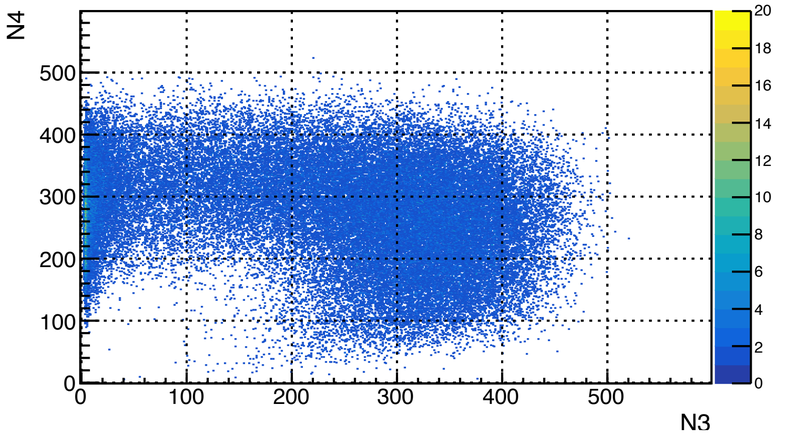
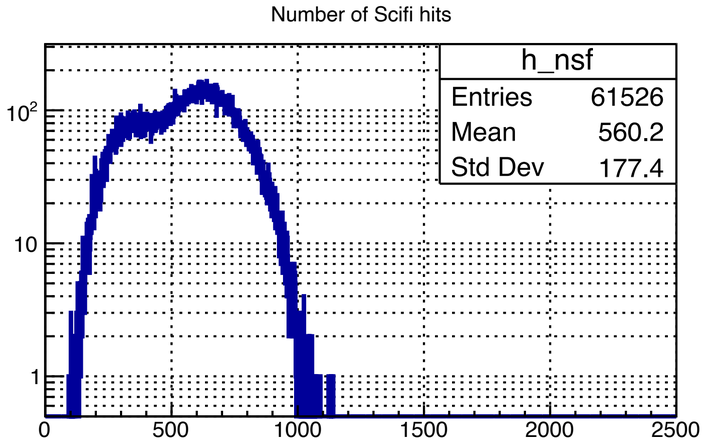
SF hits 300 GeV, 3 Target walls





100 GeV
3 Twall





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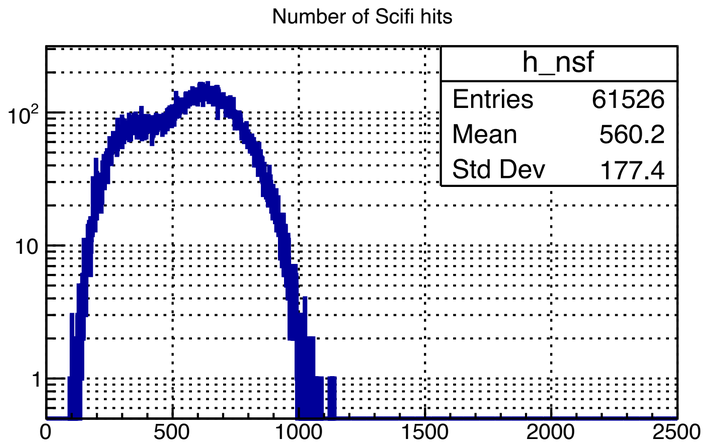
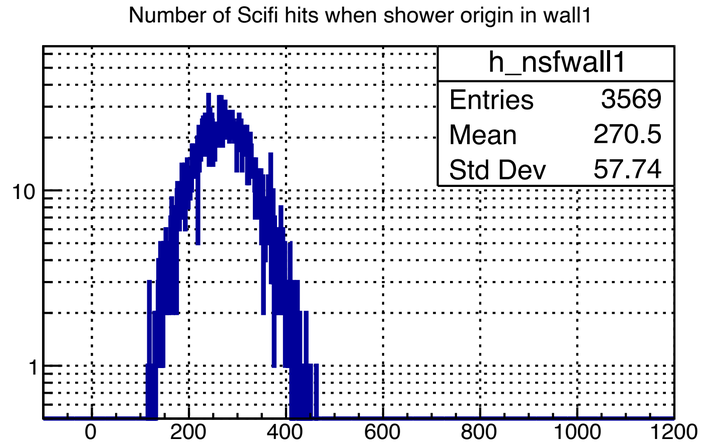
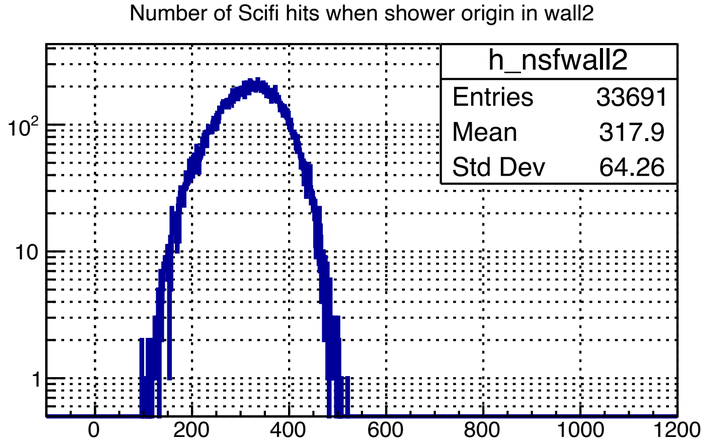
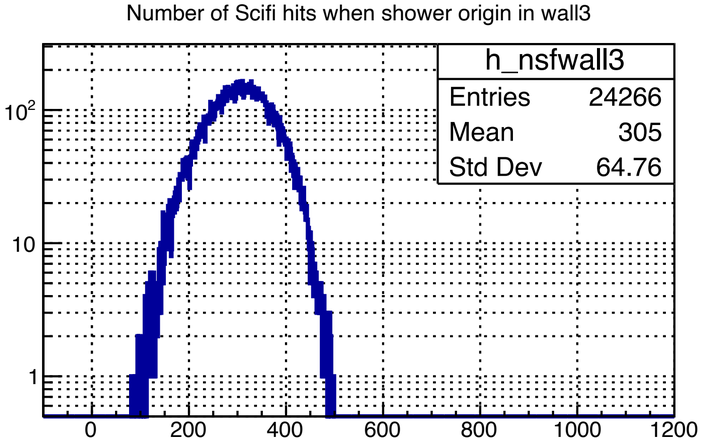
SF hits 300 GeV per shower origin , 3 Target walls









100 GeV
3 Twall

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