IceTop Veto in the Realtime Alert System

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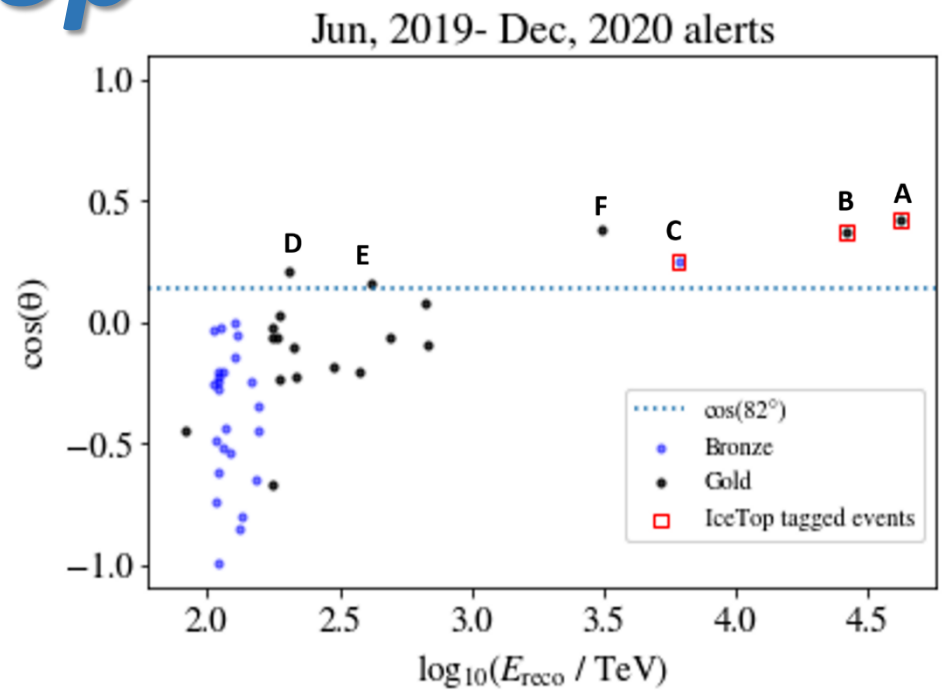
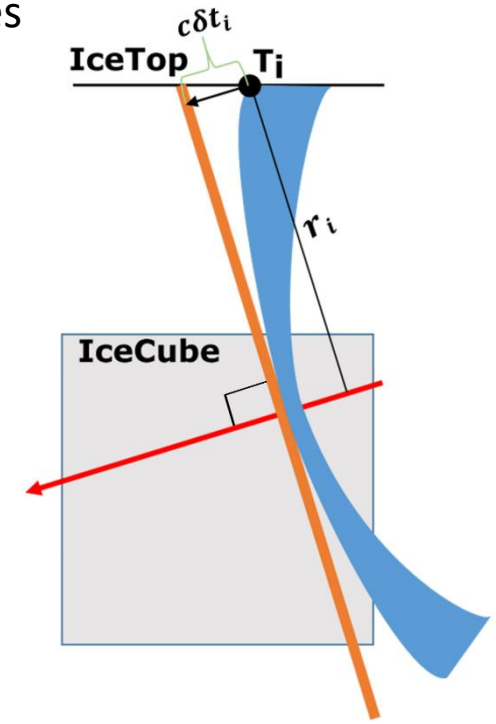
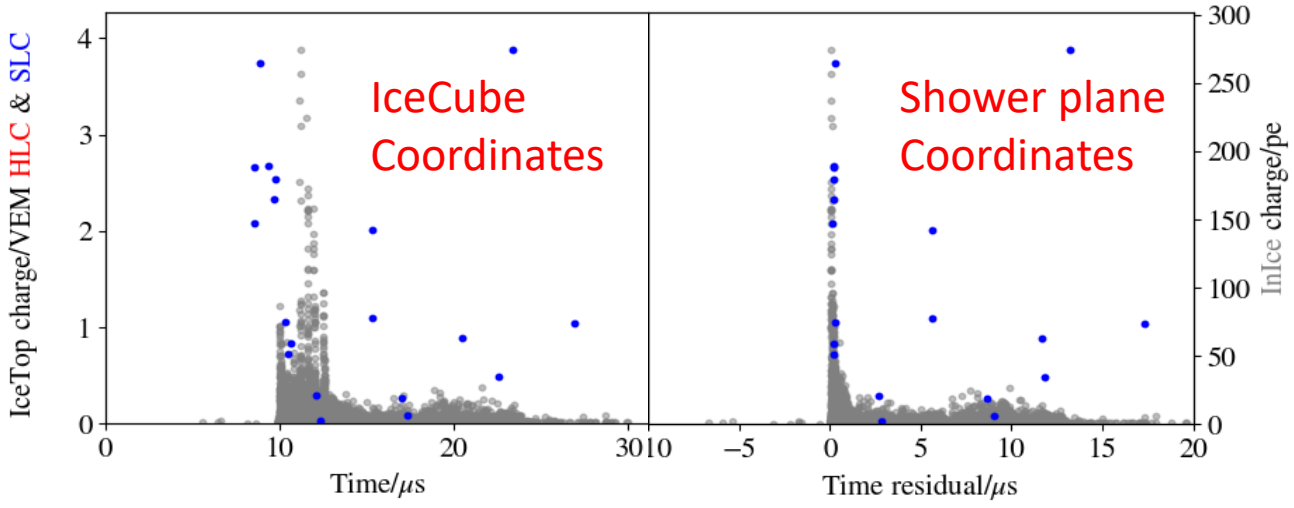
Event rejection with IceTop

- Plane shower front perpendicular to the shower track anticipates the arrival time of the shower plane on the surface
- Time residual, δt_i is the offset of hit time of particles in the shower and expected arrival time with respect to shower plane at IceTop tanks
- Correlated in-ice and IceTop pulses cluster together with small time residuals
- Define ***in-time window*** and ***count threshold*** of IceTop HLC and SLC pulses







Data set: Online alert candidates

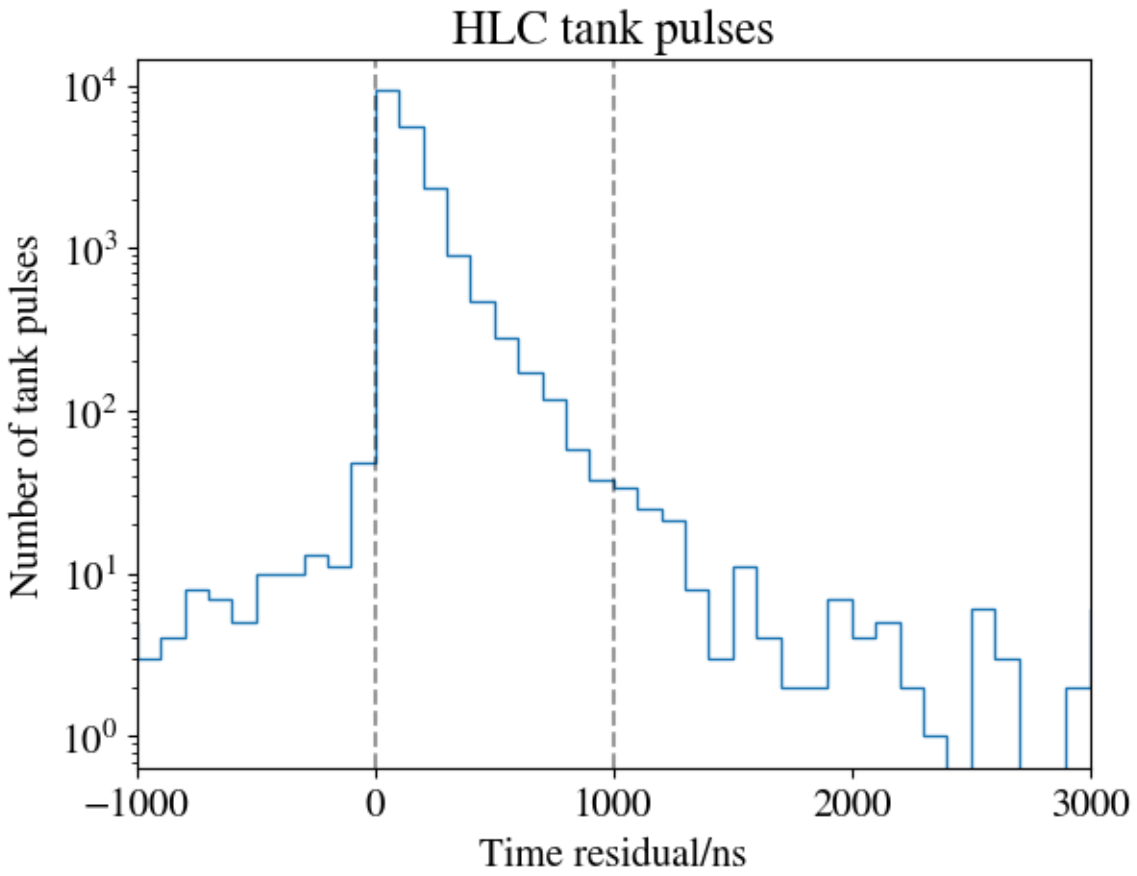
- 10% of 2017, 2018, 2019 Level2 data
- **OfflineIceTopHLCTankPulses** & **OfflineIceTopSLCTankPulses**
- OnlineL2_SplineMPE
  - $\theta < 82°$ → Down-going events
  - $\theta > 90°$ → Up-going
- Passed GFUFilter_17

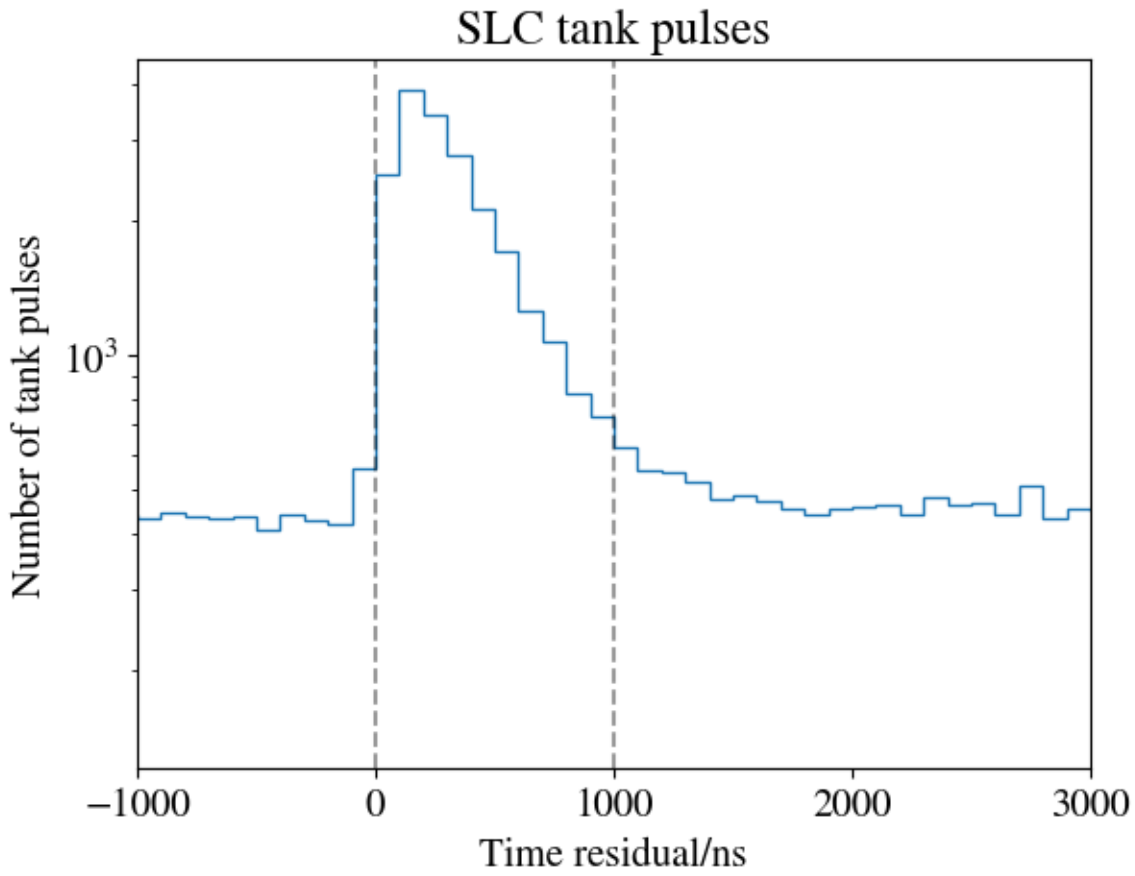
- $zenith < 82°$:
  - $\log_{10}(E_{MuEX}/GeV) > 2.5$ *
  - $N_{string} \geq 7$ *
  - $L_{Dir,E} > 250\ m$ *
  - $N_{Dir,E} \geq 12$
  - $\log_{10} \mathcal{L}_{SplineMPE}/(N_{Ch} - 5) < 10$
  - $\sigma_{Cramer-Rao} < 10°$
  - $CoG_\rho < 540\ m$
  - $CoG_z \leq 480\ m$
  - $L_{Sep} > 75\ m$
  - $\log_{10}(q_{max}/q_{tot}) < -0.2$
  - $cos\angle(SplineMPE, PoleMuonLineFit) > 0.73$ *
  - $\log_{10} \mathcal{L}_{DDDDR}/N_{Ch} > 0.14$
  - $\log_{10} \mathcal{L}_{TRes} > 11$
  - $BDT\ score > BDT\ cut$

- $82° \leq zenith < 90°$:
  - $E/GeV > 10$
  - $\log_{10} \mathcal{L}_{Bayesian} - \log_{10} \mathcal{L}_{SPE2it} > 20$
  - $\frac{\log_{10}\mathcal{L}_{SplineMPE}}{N_{Ch}-3.5} < 10$
  - $AvgDistQtotDOM < 250$
  - $\log_{10}(N_{ch}) \geq 6$
  - $N_{Dir,E} \geq 6$
  - $CoG_z < 500\ m$
  - $\sigma_{Cramer-Rao} < 25°$
  - $|\vec{v}| < 3$
  - $CoG_\rho > 75\ m$
  - $L_{Empty} < 600\ m$
  - $BDT\ score > BDT\ cut$

- Down-going events → 22236 and Up-going→ 33804

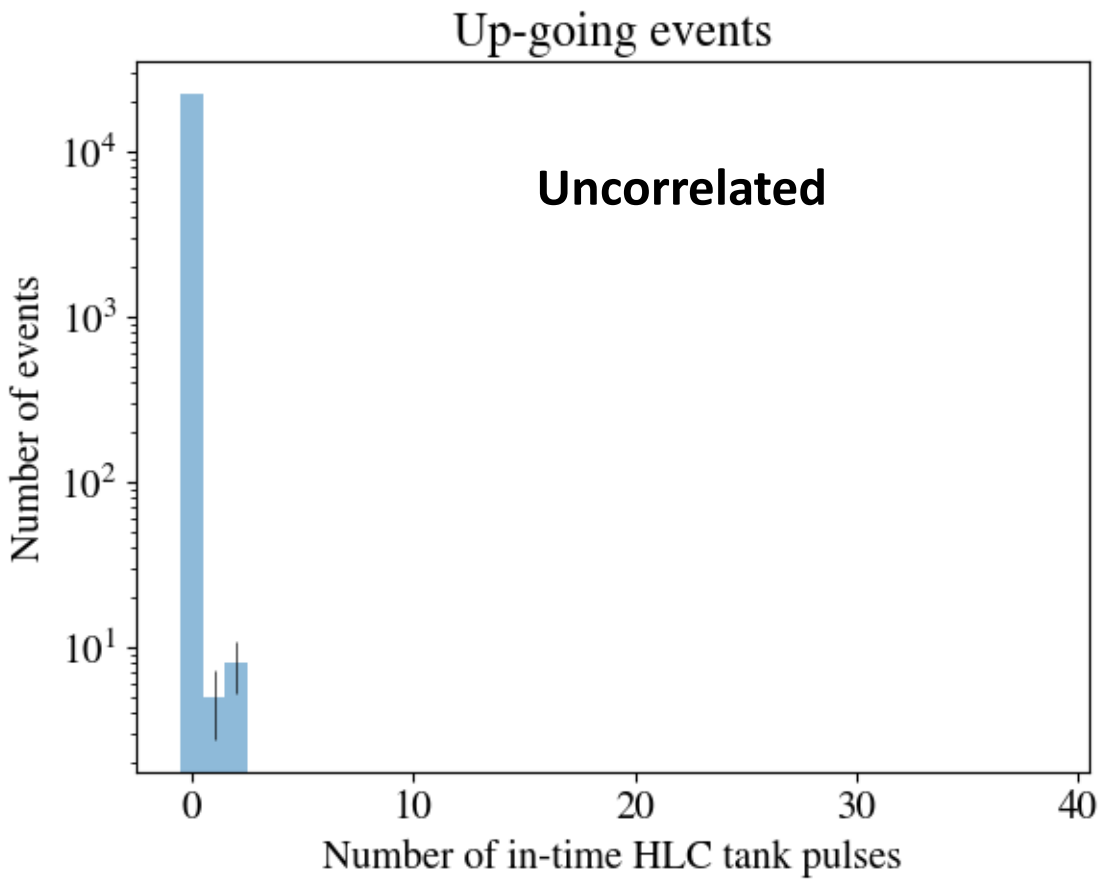
In-time window

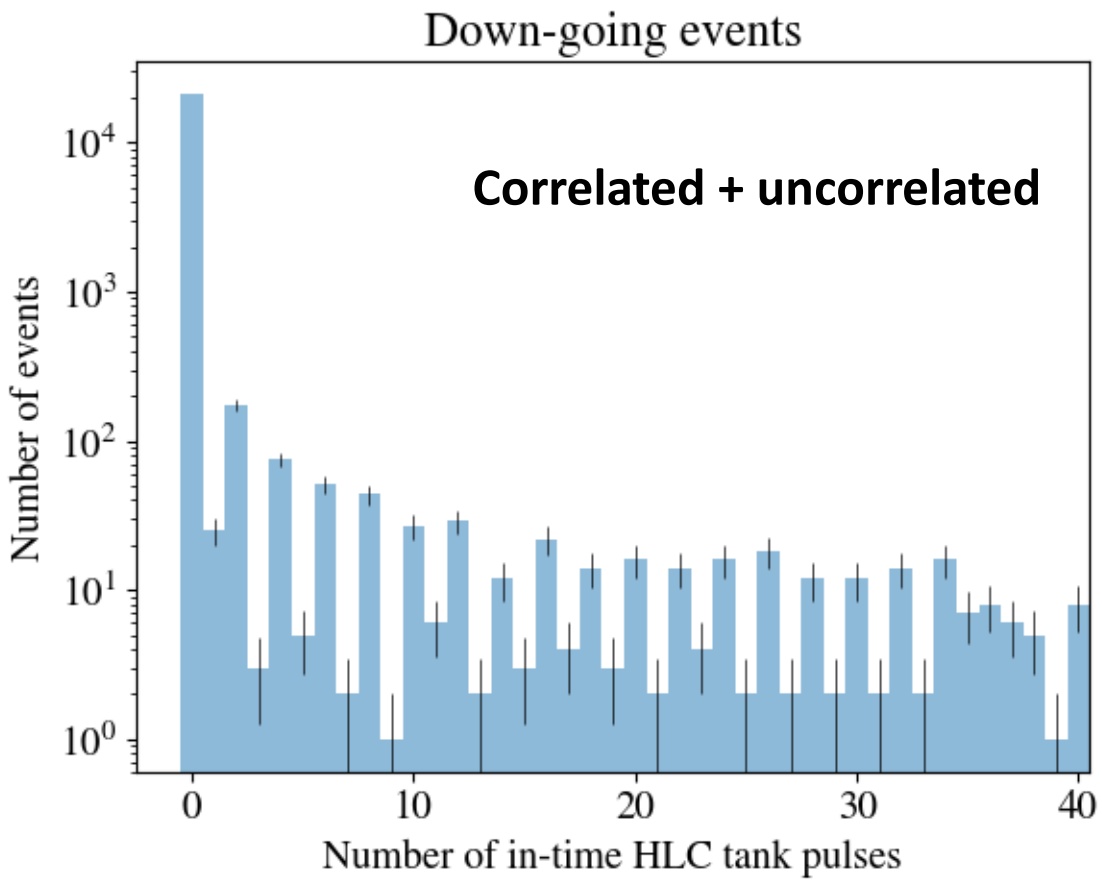




Dotted gray lines→ 0 & $1000\ ns$

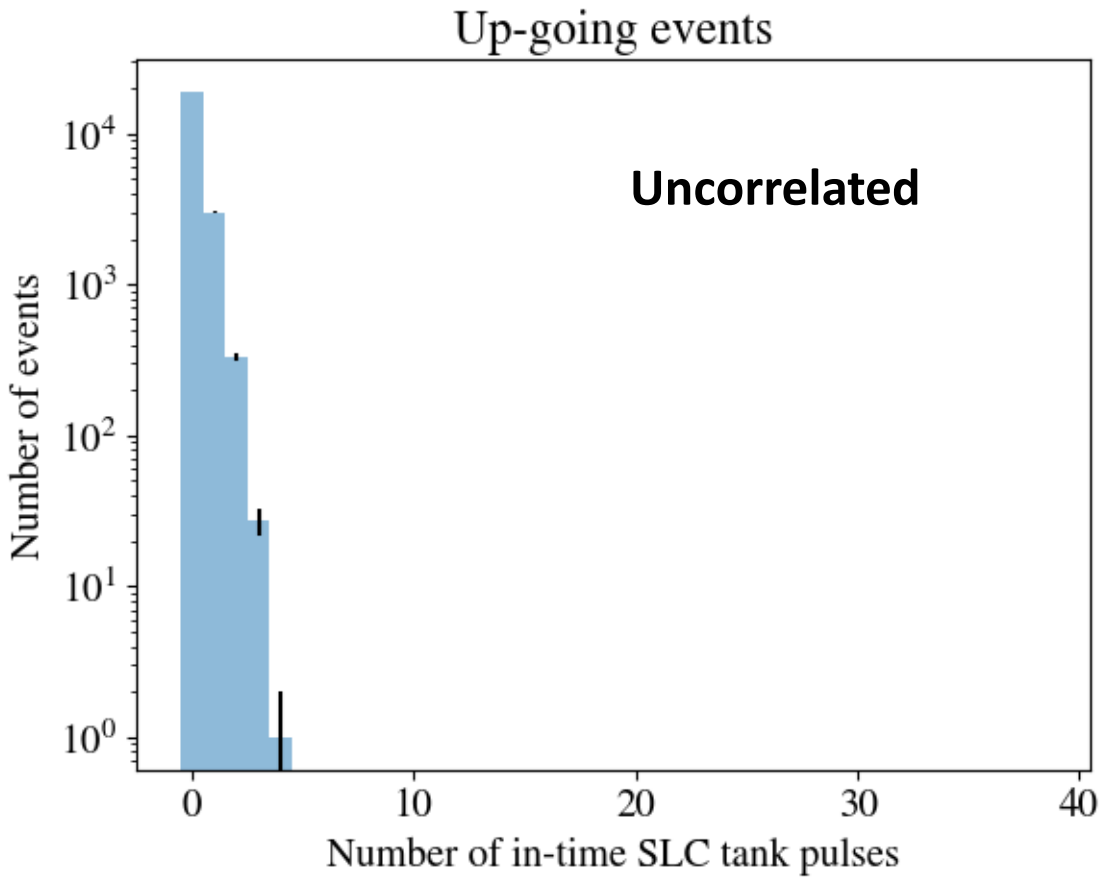
Defining threshold of HLC tank pulses

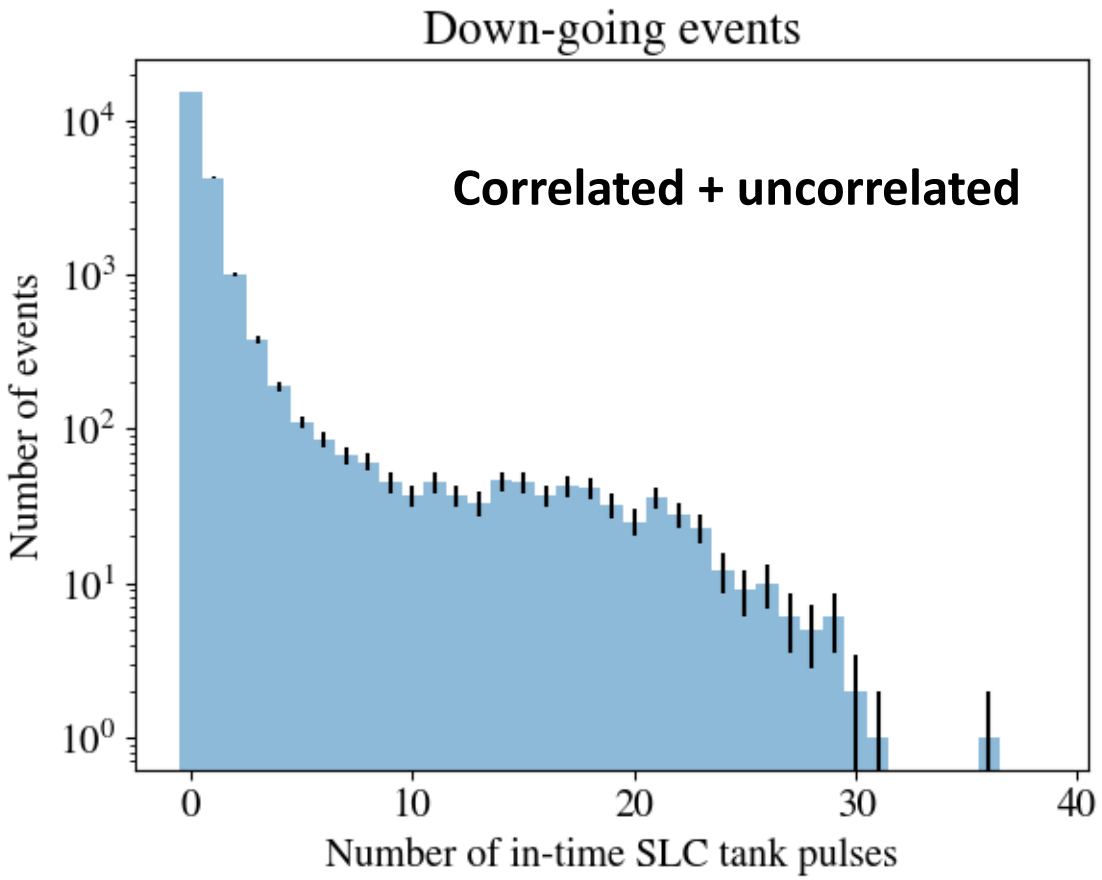




More than 2 HLC Tank pulses-> *"Cosmic ray event"*

Defining threshold of SLC tank pulses





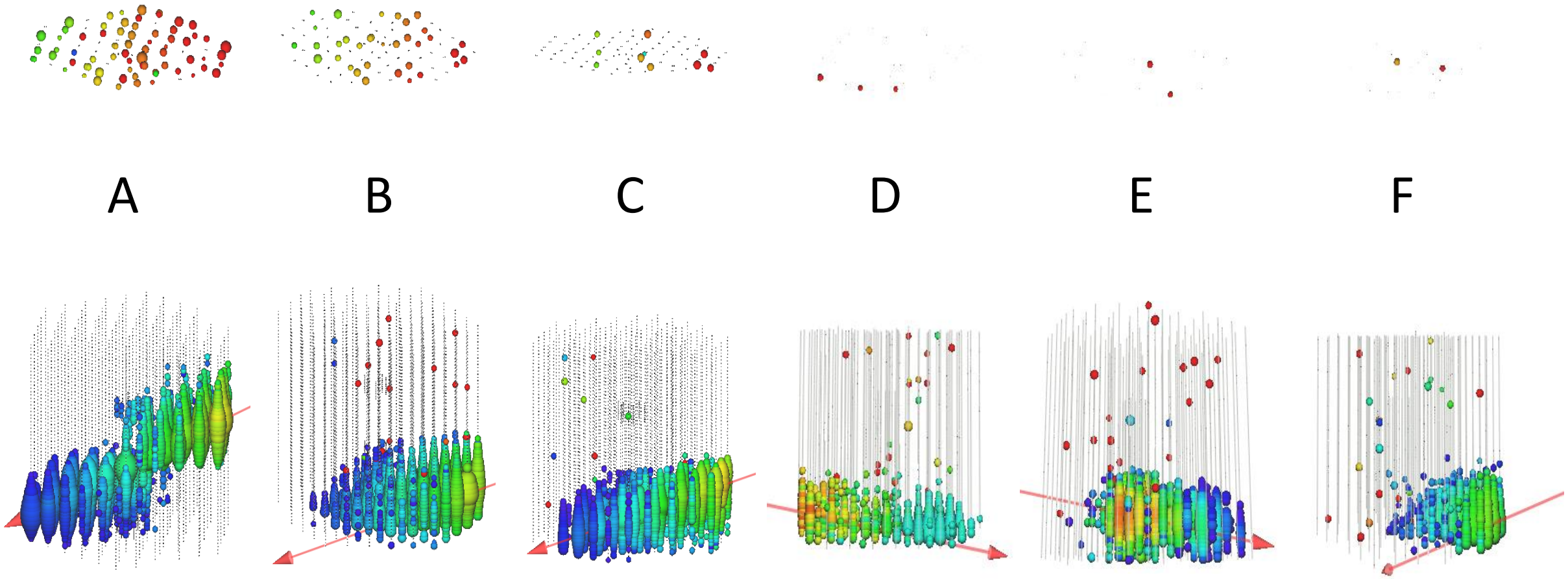
More than 4 SLC Tank pulses-> *"Cosmic ray event"*

IceTop activity in alerts from June, 2019 to December, 2020

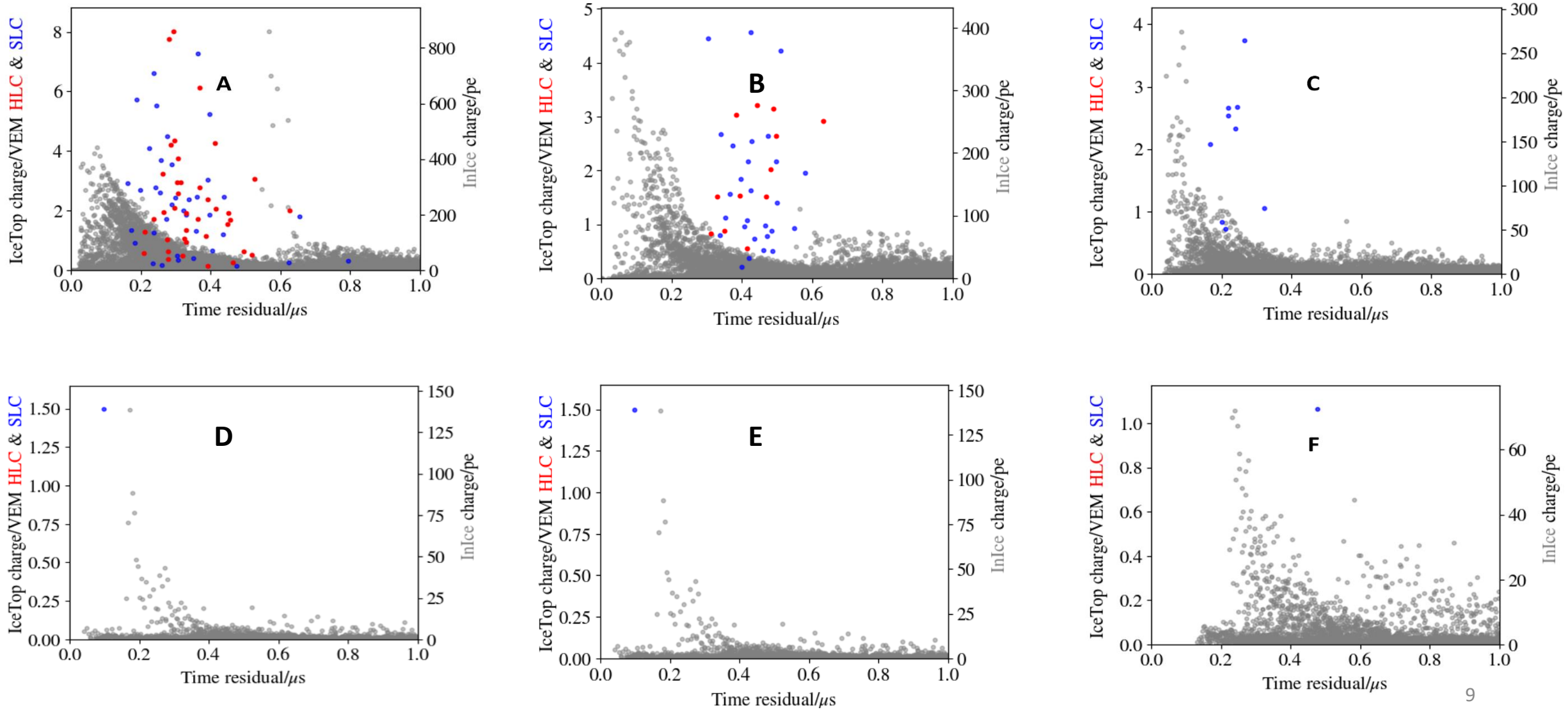
Table of down-going ($\leq 82°$) alerts

	Zenith/°	E_{reco}/TeV	r/m	HLC	SLC
A	65.10	42024	1885	38	38
B	68.26	26182	2335	12	27
C	75.45	6055	2233	0	9
D	78.48	203	2387	0	1
E	80.01	419	2246	0	0
F	65.39	3114	2346	0	1

Event view of six down-going alert events

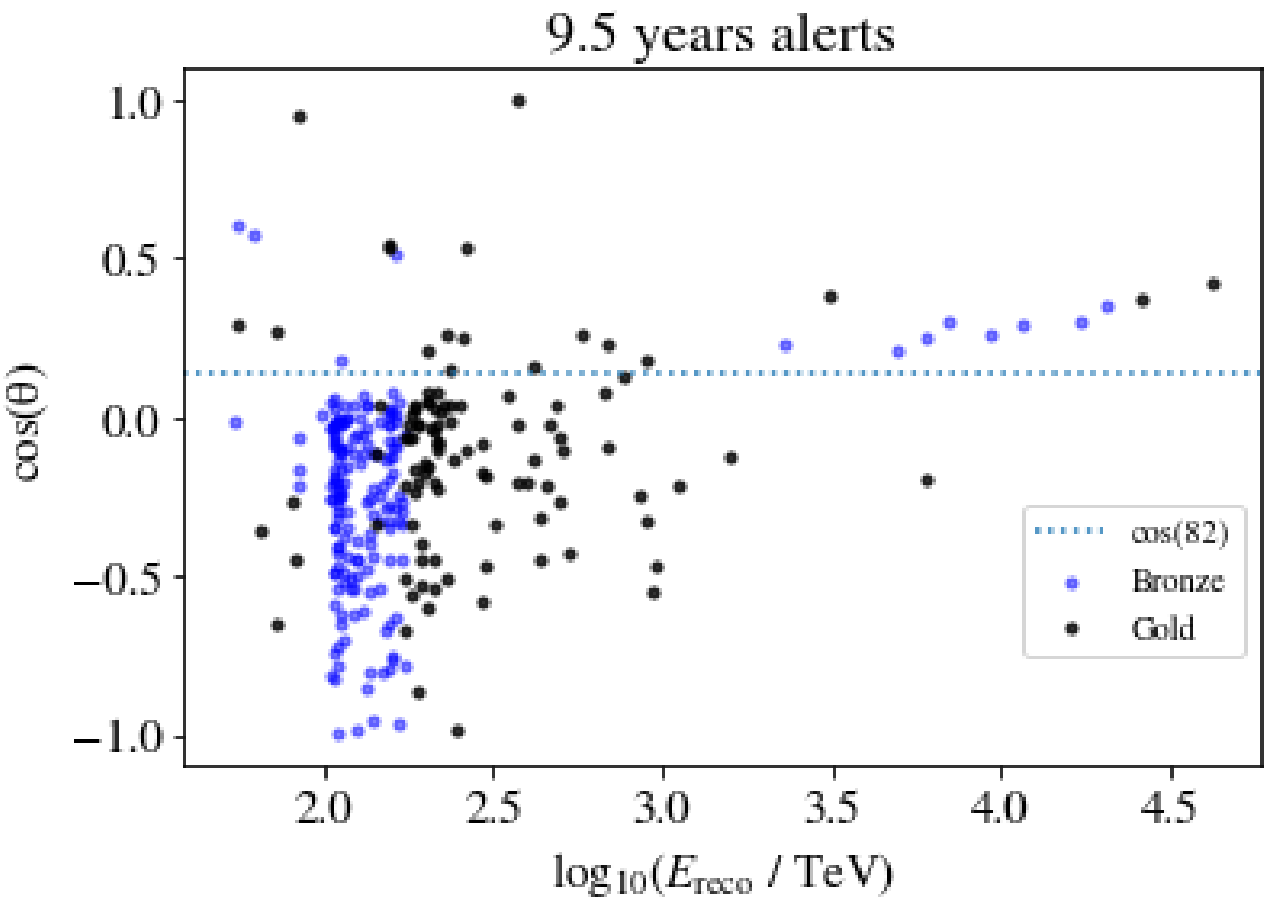


IceTop activity in down-going alert events

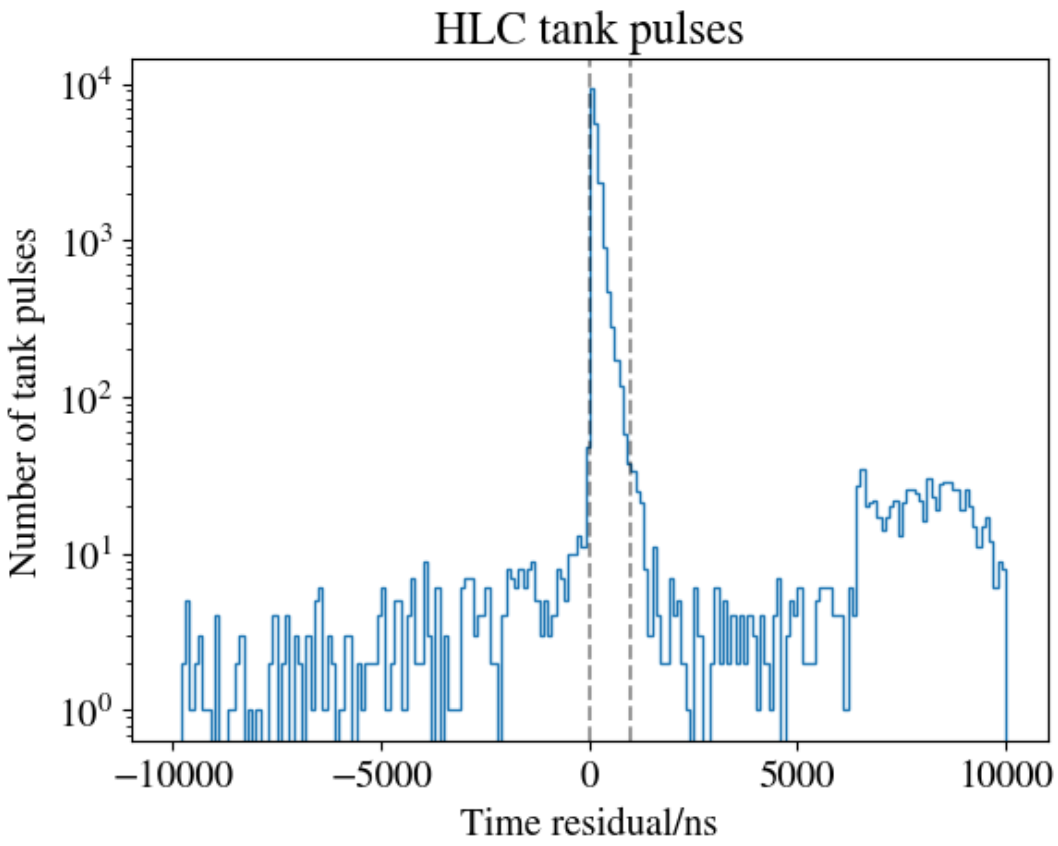


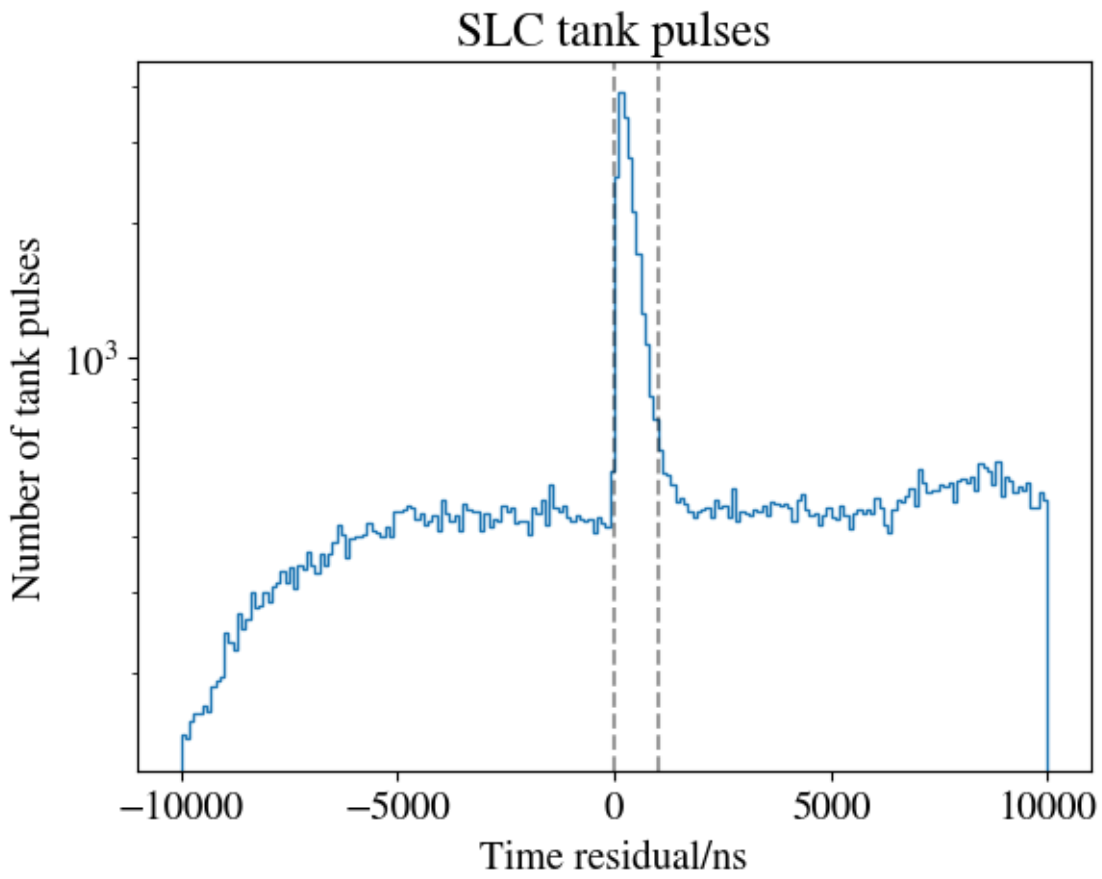
Summary and Future plans

- Transformation from IceCube coordinates to shower plane coordinates
- In-time window→ $0\ to\ 1\ \mu s$
- Threshold count for in-time pulses : > 4 SLC or > 2 HLC pulses → IceTop Activity: cosmic ray event
- IceTop Activity is used to tag 3 highest energy alerts
- Analyze 9.5 years alert Catalog



In-time window: 1D Histogram





Dotted gray lines→ $\mathbf{0}$ & $\mathbf{1000}\ \boldsymbol{ns}$