UoM X-LAB Activities 2024-25

February 2025, Paarangat Pushkarna

Matteo Volpi, Paul Giansiracusa, Joel Valerian, Roger Rassool, Suzie Sheehy, Paarangat Pushkarna, Eugene Tan, Rohan Dowd

Short introduction – Joel Valerian

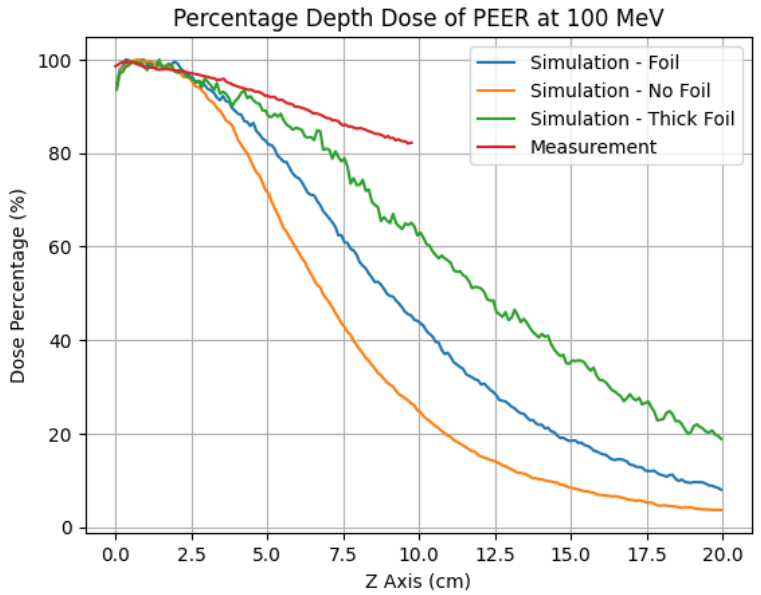
BS in Physics 2018 - 2022

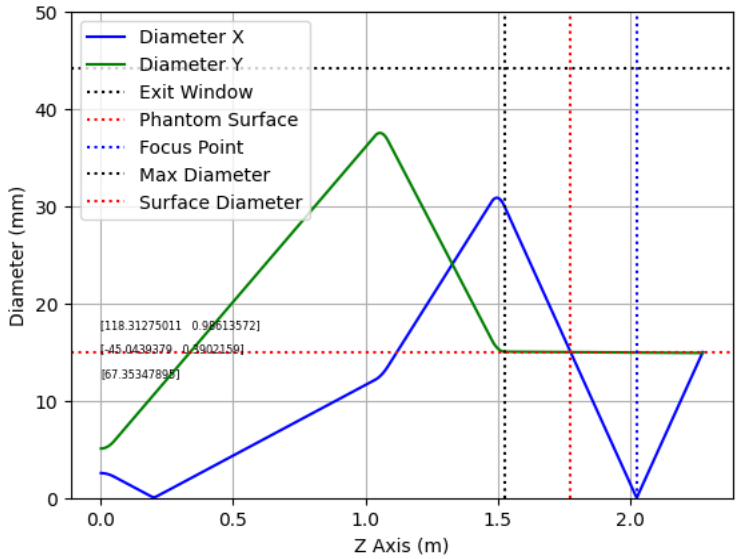
Work in Data/IT 2022 - 2024

PhD July 2024 - Now

Supervisor: Suzie Sheehy

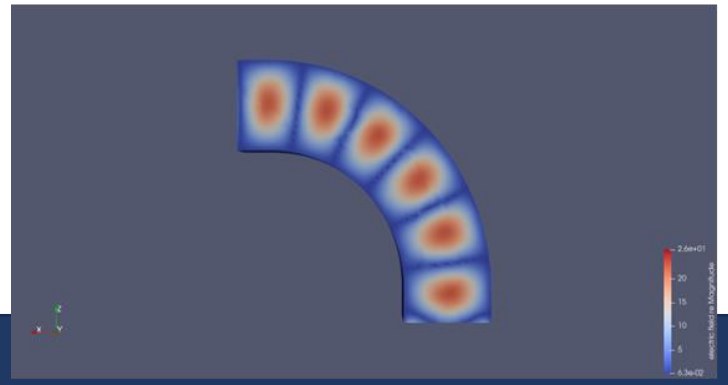
Co-Supervisor: Matteo Volpi

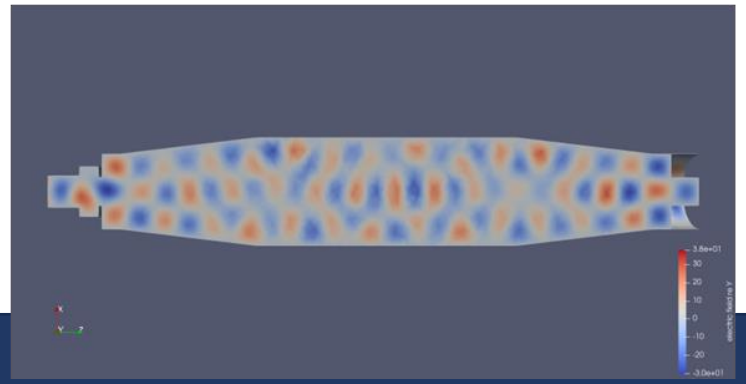


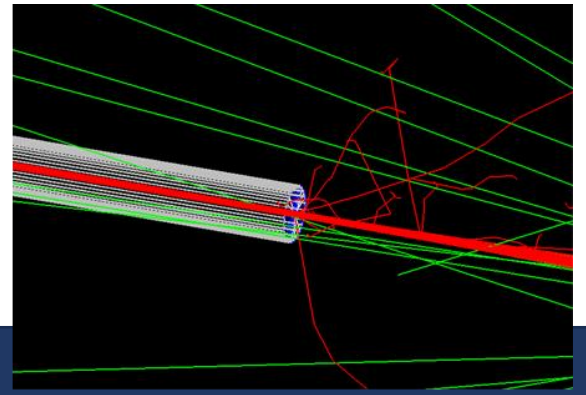


Research:

- Very High Energy Electron Beams for Radiotherapy (Beamline & Dosimetry)
- X-Band Accelerator (RF & Particle Tracking)



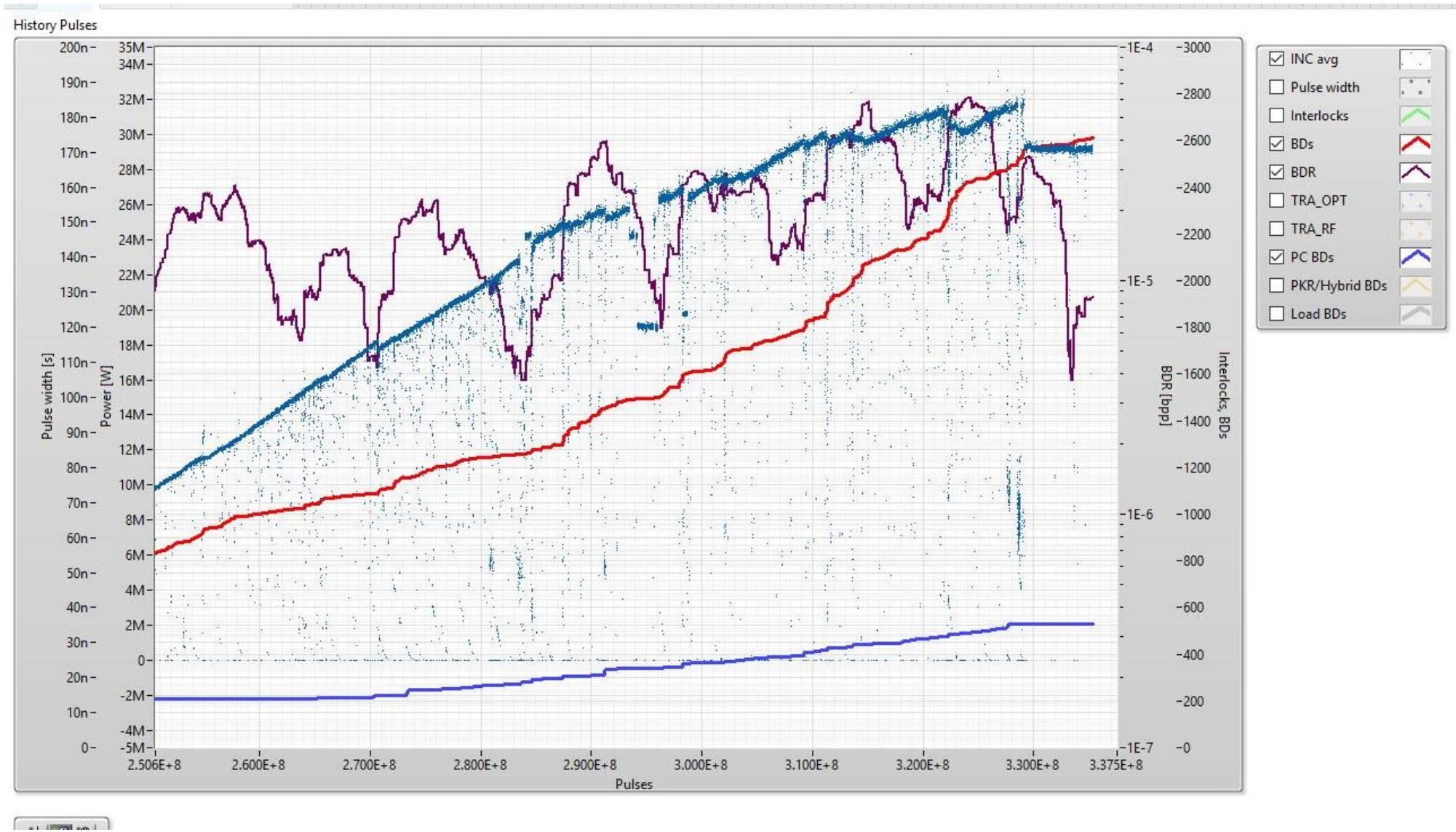




Short introduction – Paarangat Pushkarna

- BSc Physics 2018-20; MSc Physics 2021-22
- Masters:
  - Synchronisation of pressure TREND data with Breakdown Timestamps
- PhD start Aug. 2023
  - Tackling:
    - Novel RF breakdown diagnostics
    - Longitudinal bunch profile reconstruction (Aus. Synch.)
  - Using:
    - Cherenkov radiation in optical fibers

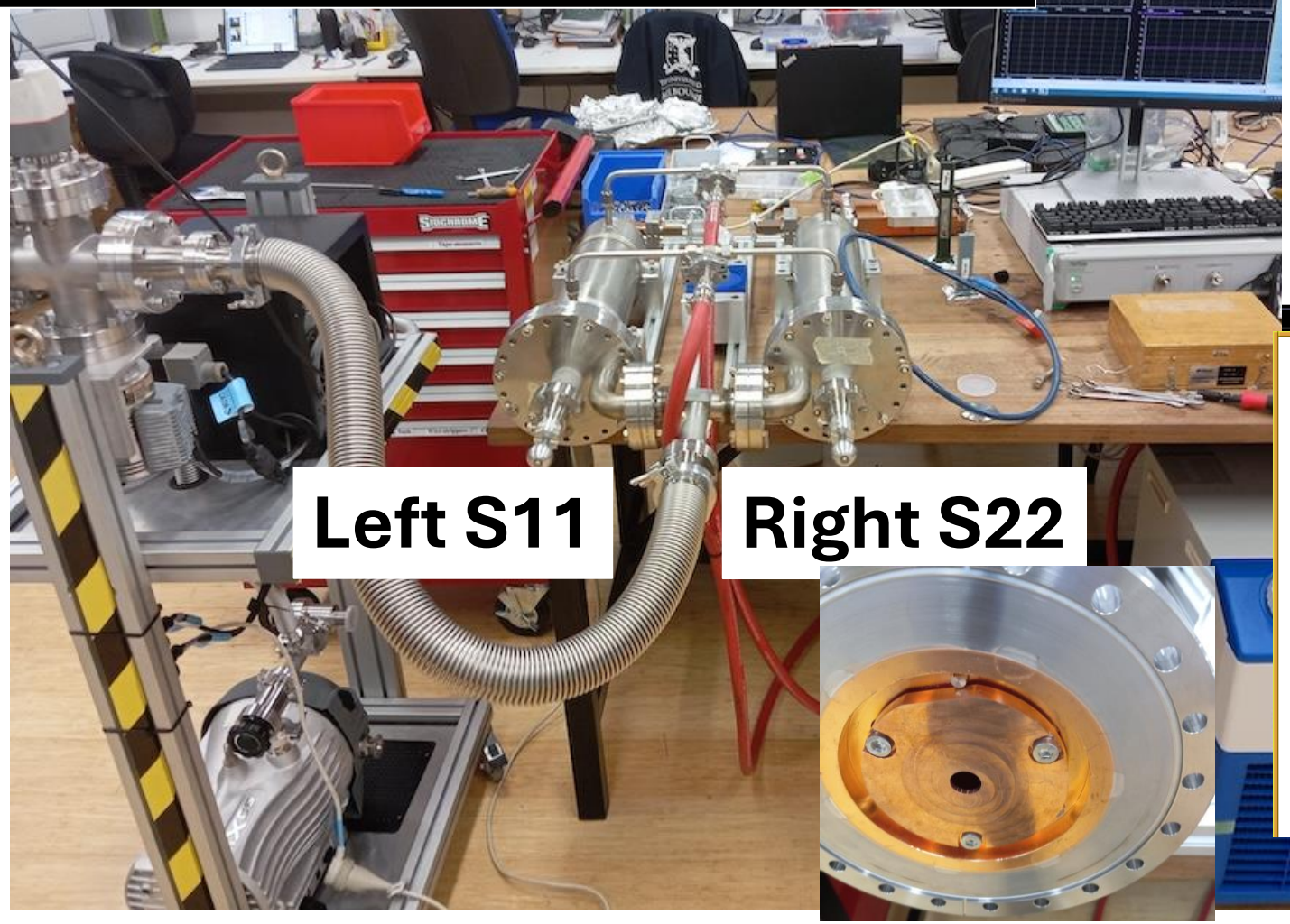
TD24 Conditioning plot Line 4

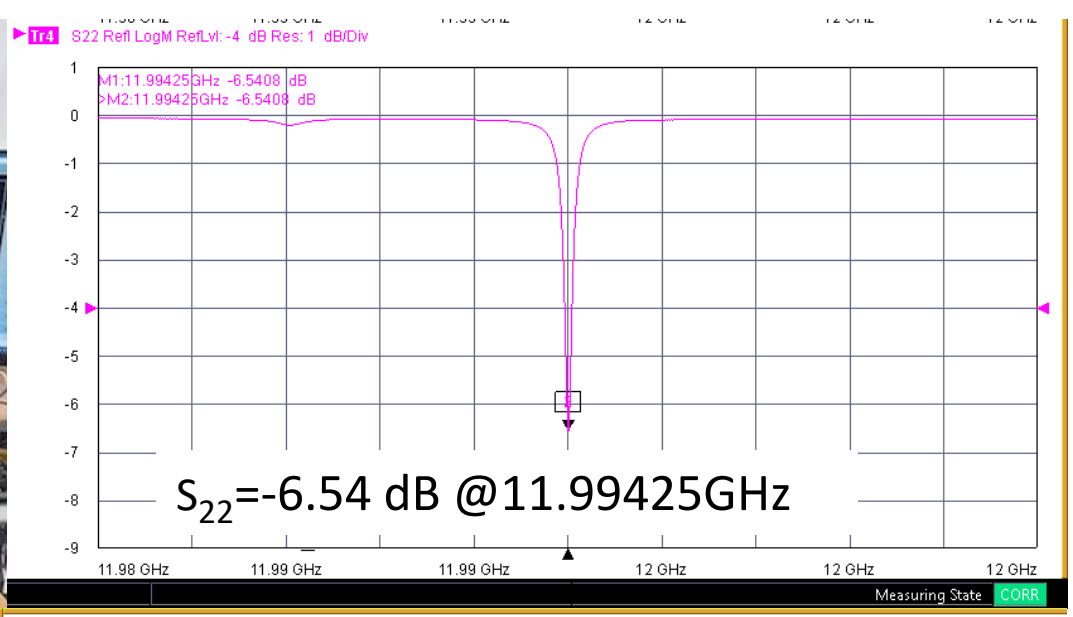


Pulse counter reset?

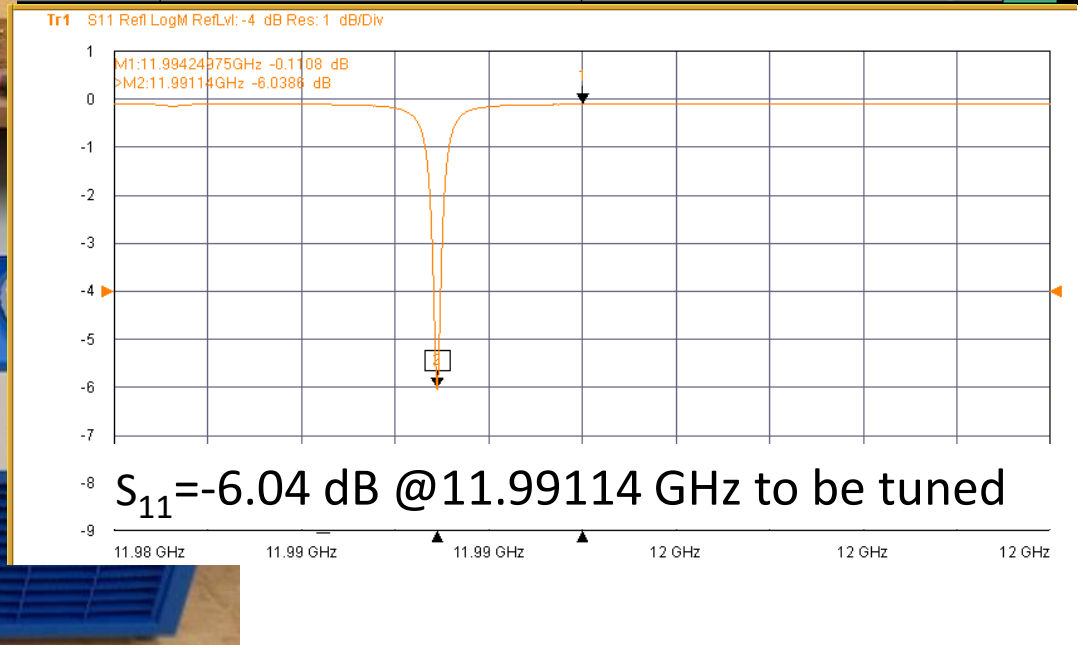
Pulse COMPRESSOR – Tuning

One cavity tuned at 11.99425GHz
28.3C + vacuum
Next step machine the other cavity





S_{22}=-6.54 dB @11.99425GHz



S_{11}=-6.04 dB @11.99114 GHz to be tuned

Dark current waveform inspection

Preliminary breakdown analysis, Paarangat Pushkarna

Context – Dark current waveform inspection

1. MDDF model: dark current fluctuations (Ashkenazy et al, 2018-2020)

2. Fluctuations detected in DC Spark but not in RF (Paszkiewicz, 2021)
    1. Novel diagnostics suggested, RF cavs (Paszkiewicz, 2021)

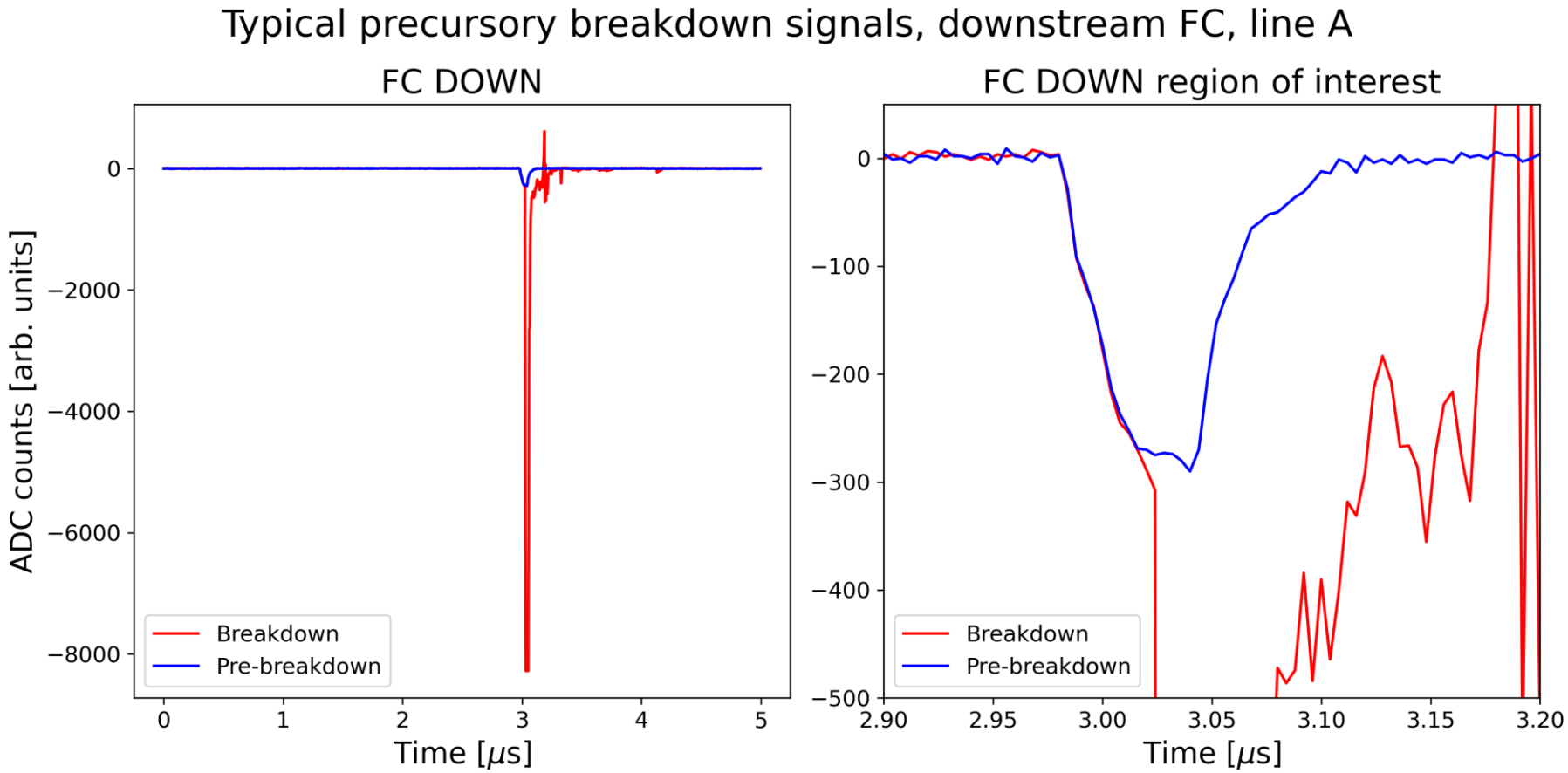
3. ML models emphasised dark current importance (Obermair, 2022)

4. Fibers were trialled for Field Emission (Wolfenden et al, 2023)
    - Were well correlated with RF pulse length

- Goal: Use optical fibers to inspect MDDF pre-cursors
- Short term: Get familiar with DC waveform shape

Main observations –TD24BO + TD24UBO

- TD24BO installed line A
- TD24UBO installed line B
- From 2018 to 2019, Xbox3 data



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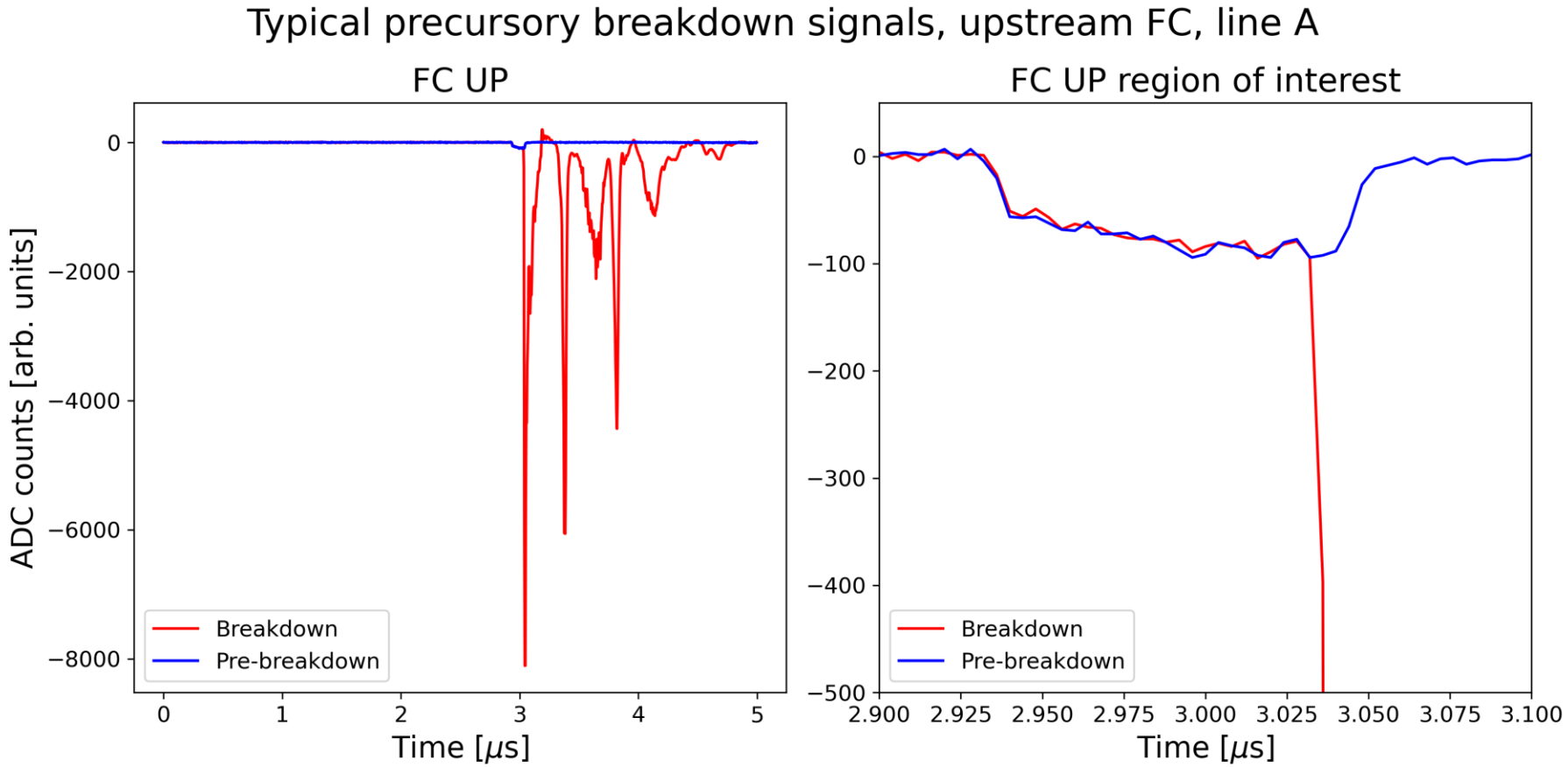


Main observations – Dark Current

- Pre-breakdown field emission gated by flat-top incident power
- Arc ignites different times inside gate (stochastic behaviour?)
- Breakdown waveforms follow closely the pre-breakdown trajectory
  - Until BD ignition point
- Pre-breakdown activity not guaranteed but common
- Different shape of dark current signal (upstream vs downstream)

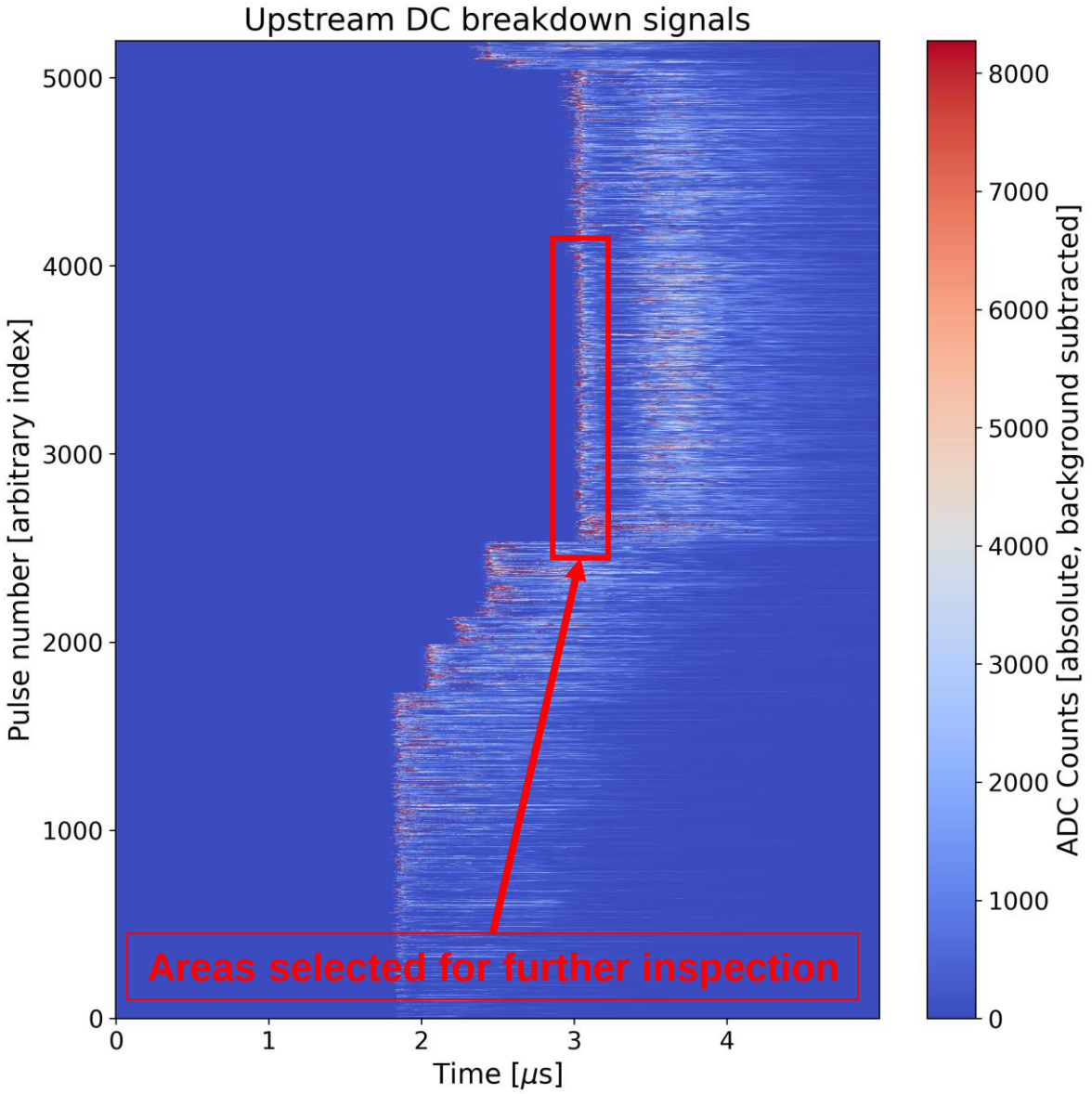
Further ideas and questions from this

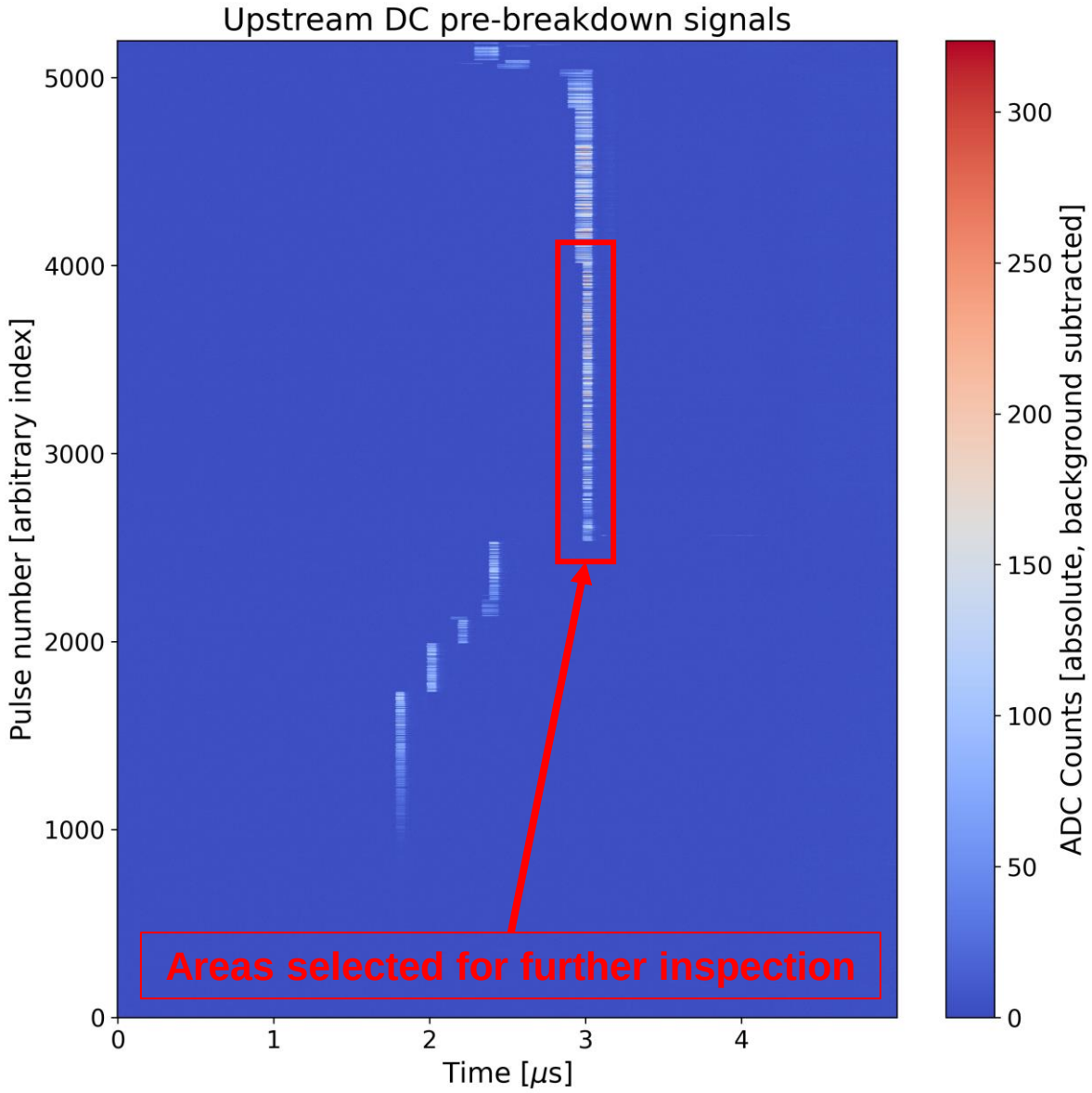
- Distribution of arc ignition times within emission gate?
- Dependence of arc ignition time on gate width?
- Is the ignition time within gate related to breakdown position?
- Percentage of pulses with/without precursory gated emission?

- But more importantly…

- Is pre-breakdown emission present in BD_{n-2}? BD_{n-3}? Or just BD_{n-1}?
- Implications for circular buffer design…
- Use of fiber to probe pre-breakdown signals, look at XB2

Typical pulse shapes





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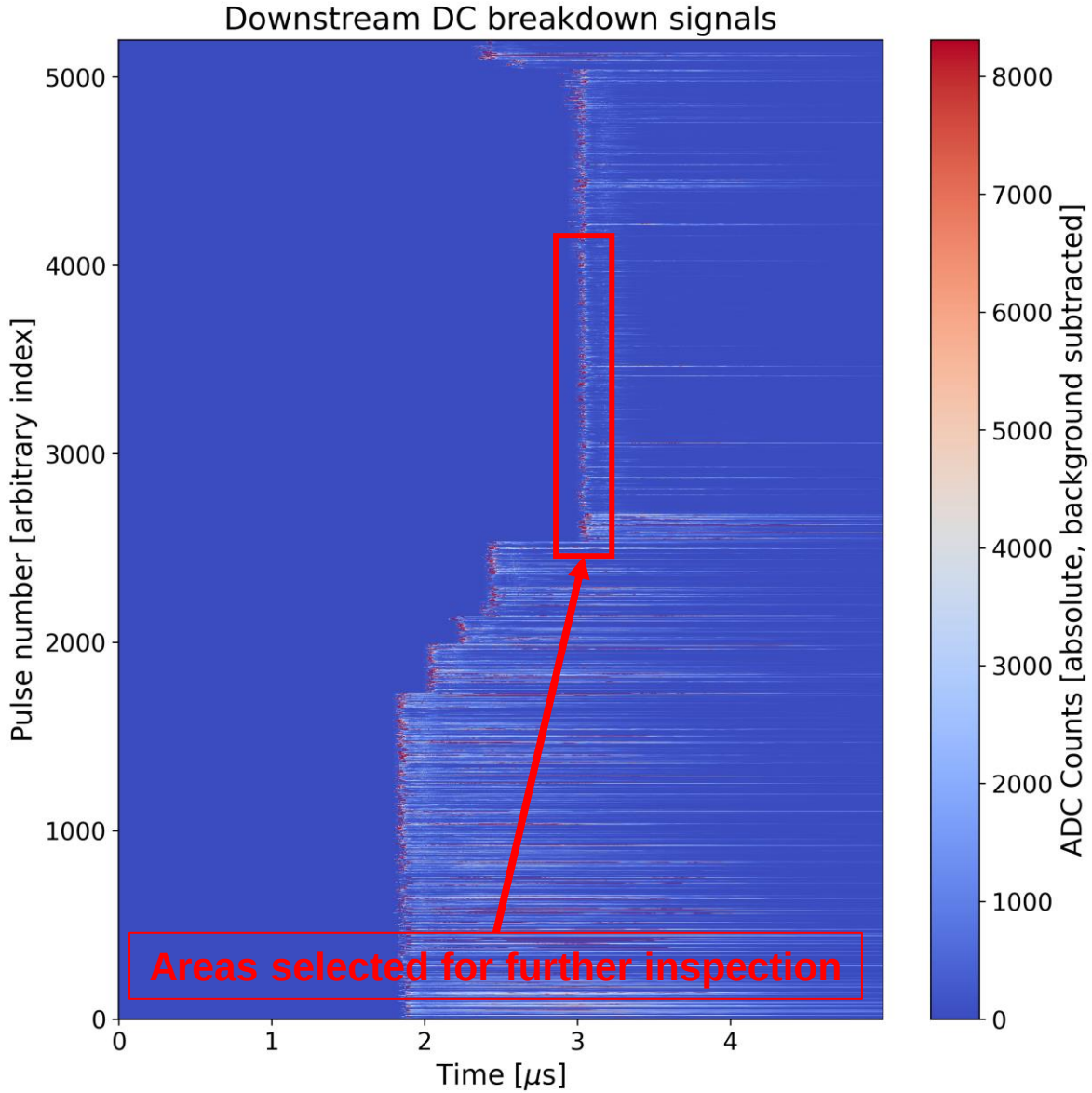

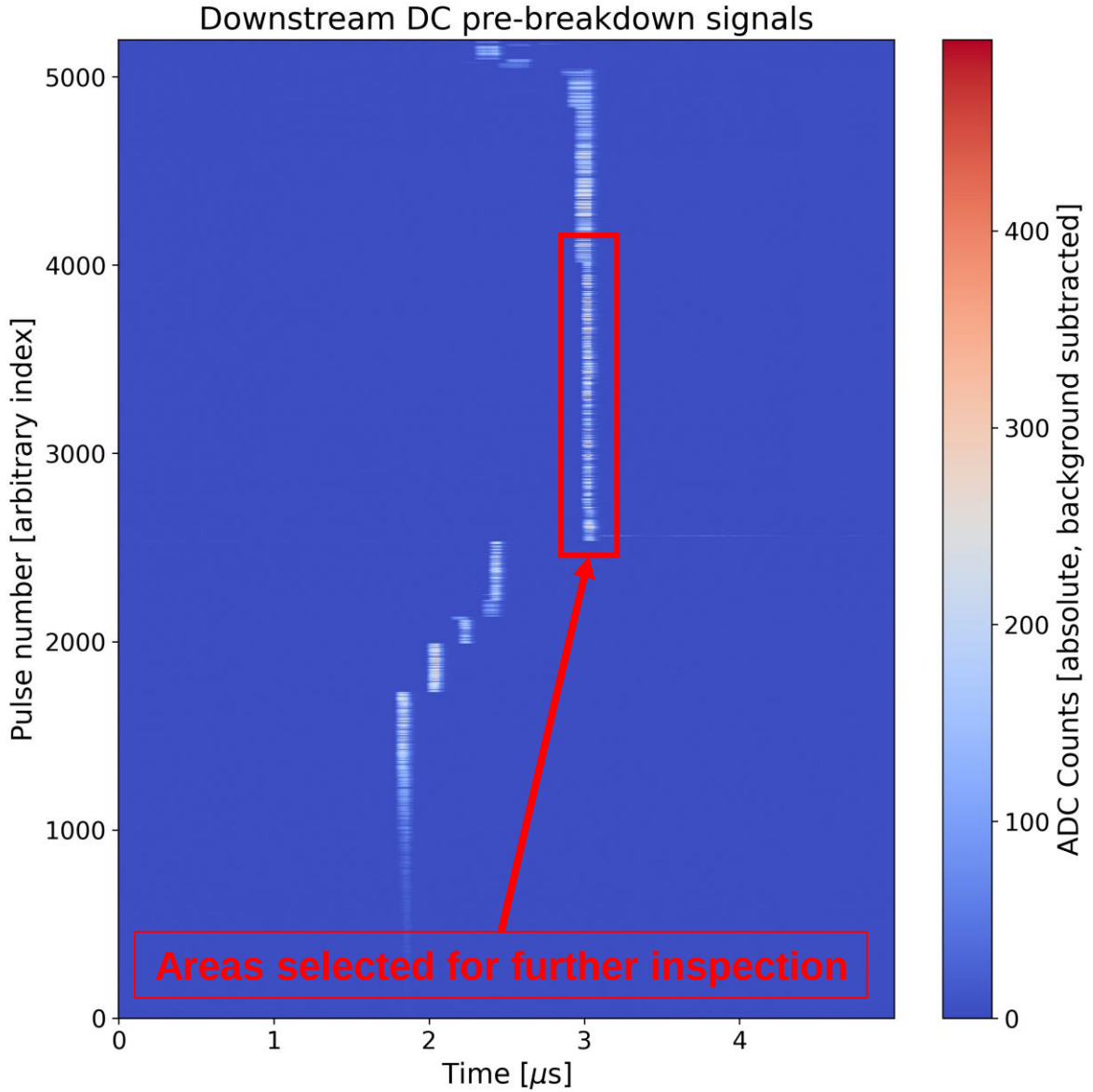

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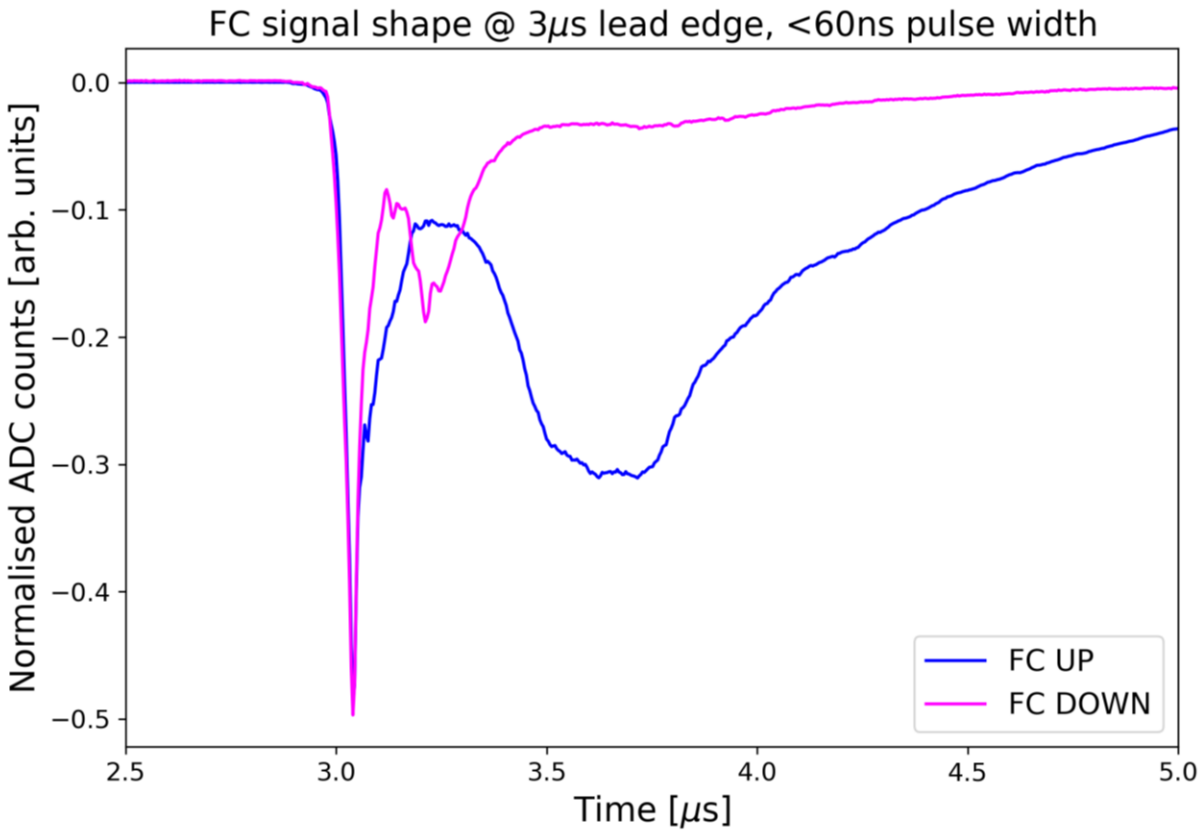
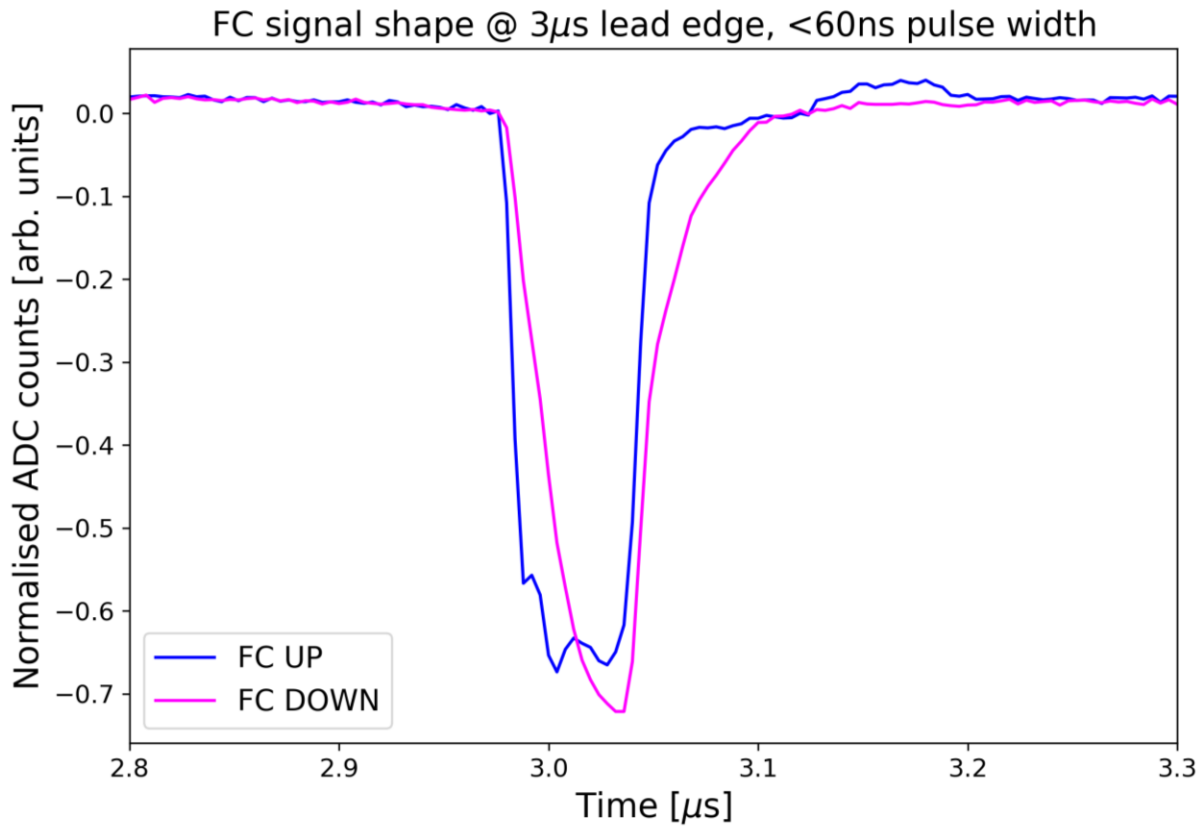




- Thought downstream will have more activity…perhaps seeing bunching longitudinally as dark current propagates? Would need help to build model…
- How to explain the second, broader “aftershock”?

Breakdown selection with missing energy

- Reflection-transmission coefficients (c.f. Robin Rajamaki + Tom Lucas)

$$U_{\mathtt{SIGNAL}} = \int P_{\mathtt{SIGNAL}}(t)\mathrm{d}t \text{ [Joules]},$$
$$P_{\mathtt{SIGNAL}}(t) = C_2(A_{\mathtt{SIGNAL}}(t))^2 + C_1 A_{\mathtt{SIGNAL}}(t) + C_0 \text{ [Watts]}.$$

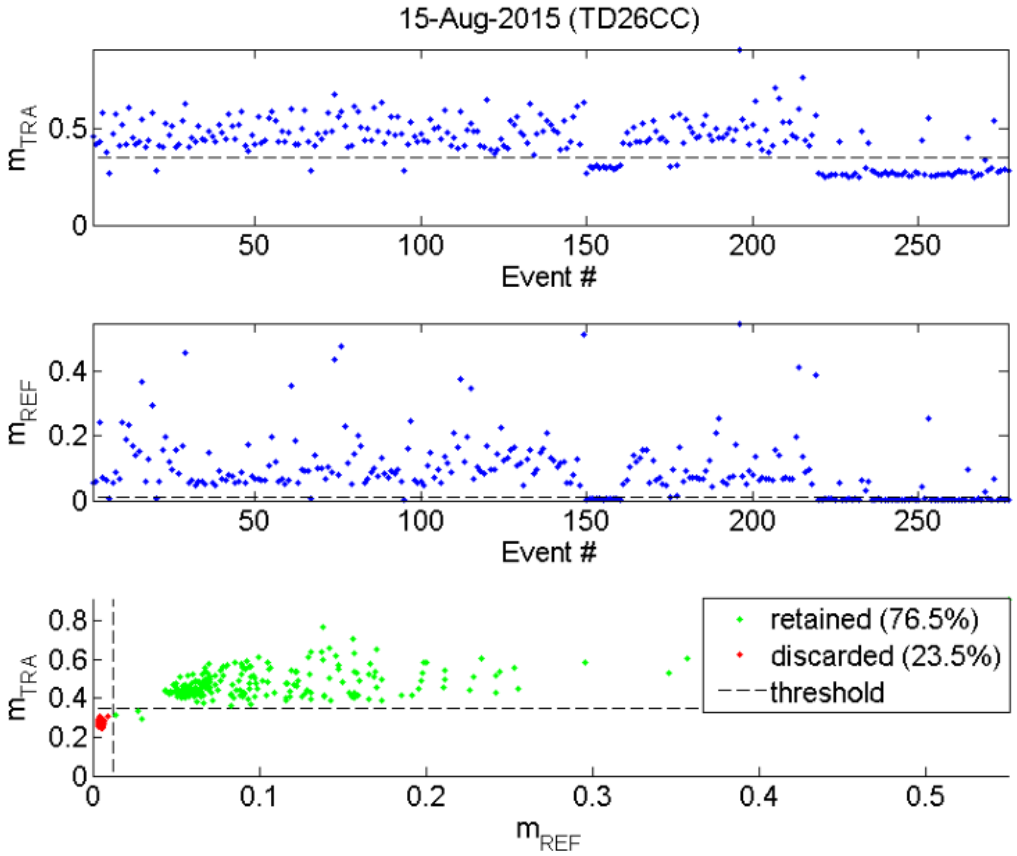
$$m_{\mathtt{TRA}} = \frac{U_{\mathtt{INC}} - U_{\mathtt{TRA}}}{U_{\mathtt{INC}} + U_{\mathtt{TRA}}} \text{ [unitless]}$$
$$m_{\mathtt{REF}} = \frac{U_{\mathtt{INC}} + U_{\mathtt{REF}}}{U_{\mathtt{INC}} - U_{\mathtt{REF}}} - 1 \text{ [unitless]}.$$

Robin's definition

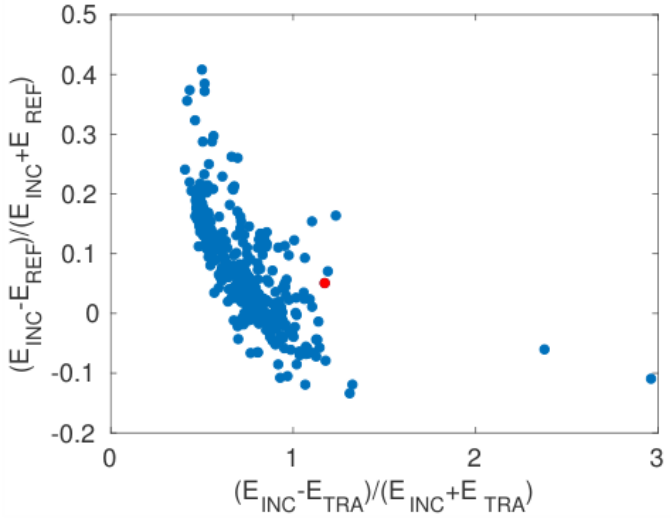
$$E_{Norm.REF} = \frac{E_{INC} - E_{REF}}{E_{INC} + E_{REF}}.$$

Tom's definition

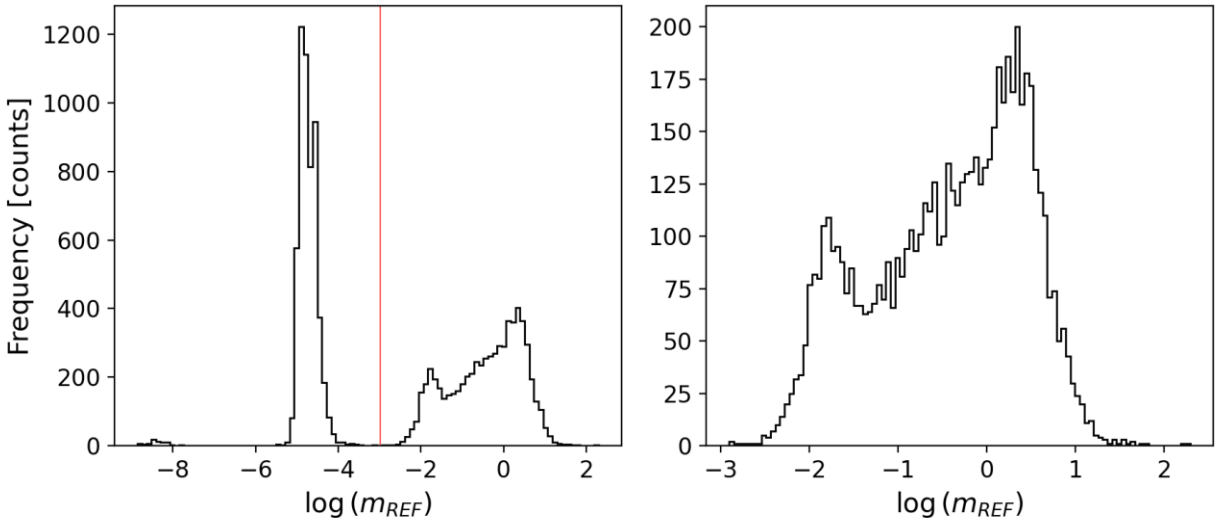
Log-space is helpful



Robin Rajamaki, 2016, Vac. Arc Localisation

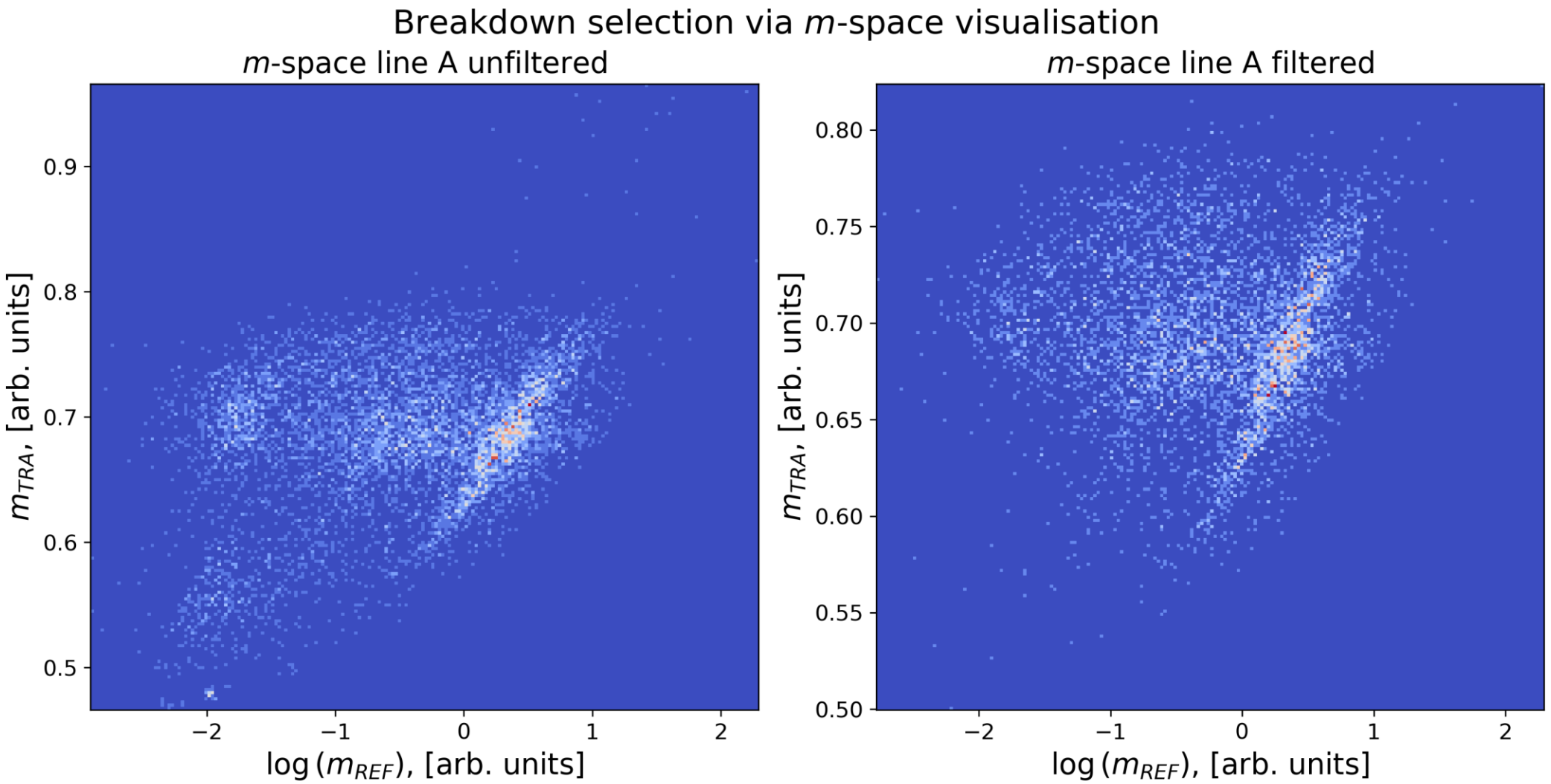


Tom Lucas, 2018, High Field Pheno.



The present analysis, 2024-25

Log-space is helpful (XBOX3 2018-19, Line A-B)



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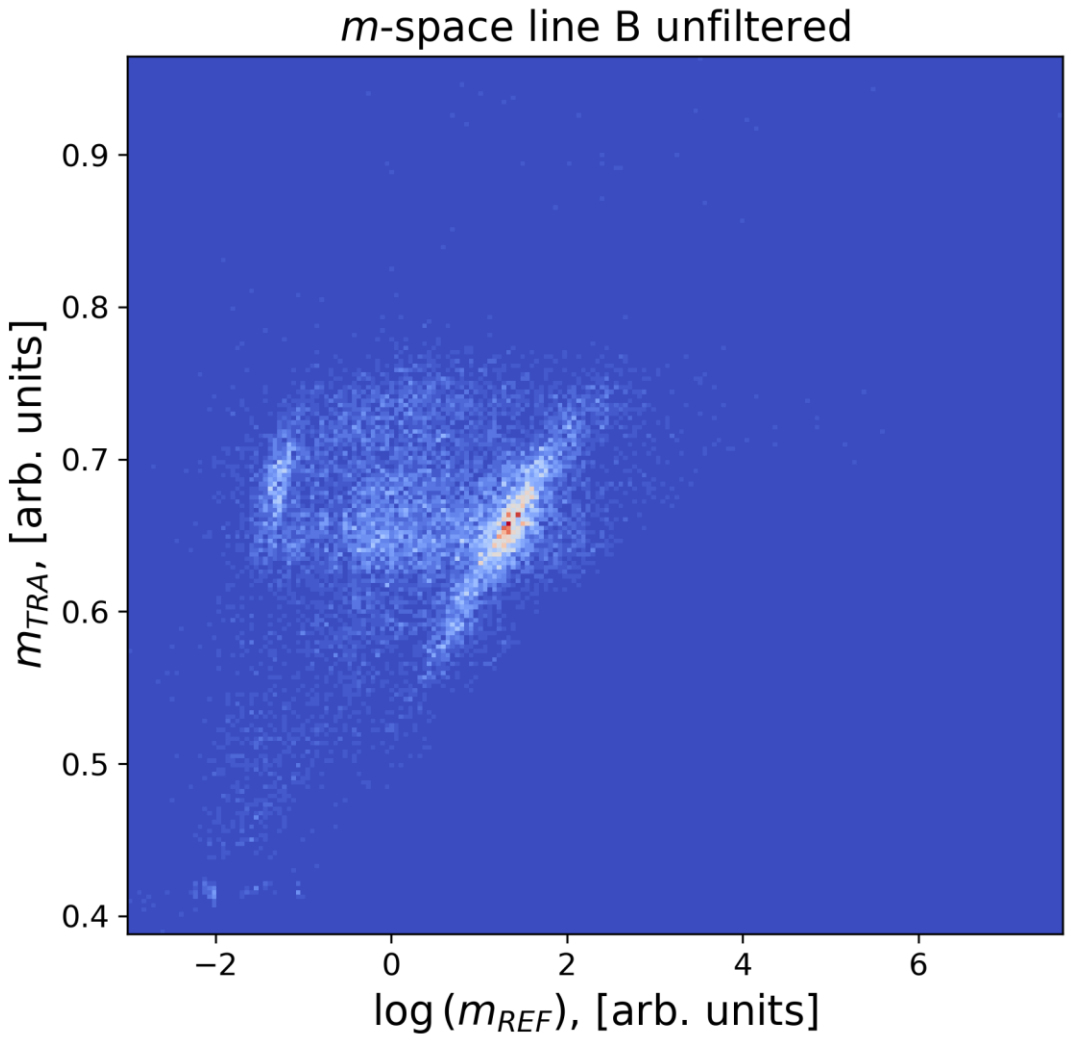
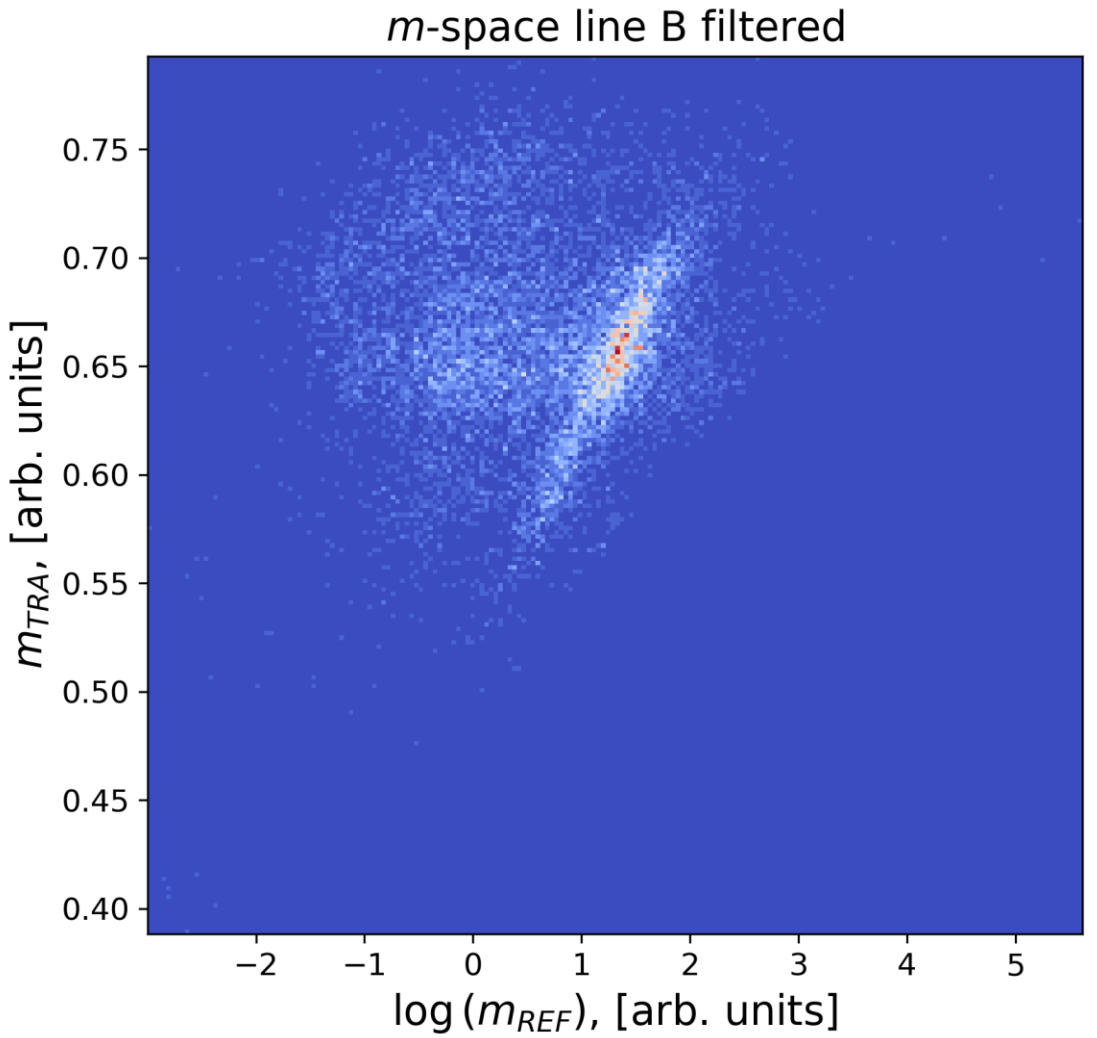




Time-of-Propagation filter – BD posn.

- $t_{TOP} = t_{rising,10\%} - t_{falling,90\%}$ as defined in T. Lucas thesis, 2018
- But this has boundary conditions! You can't exceed structure fill time:

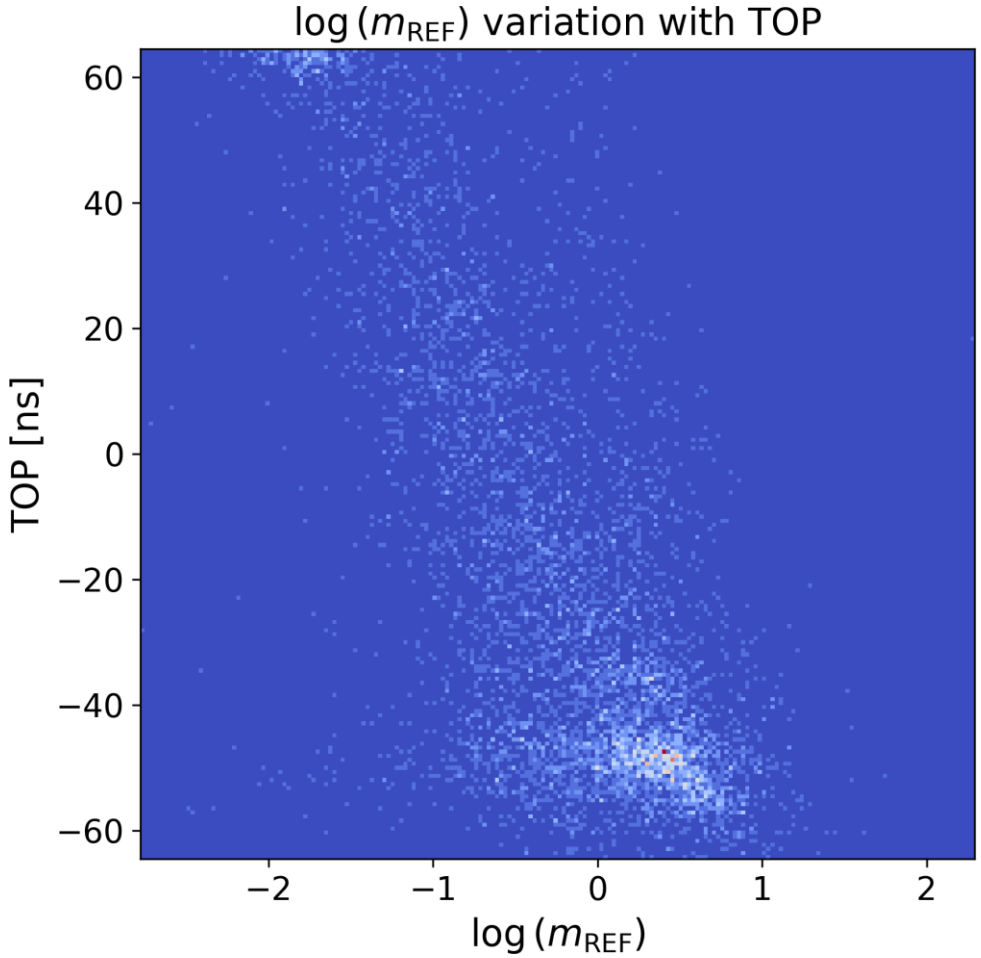
$$t_{\mathrm{TOP}} \in [-t_{\mathrm{fill}}, t_{\mathrm{fill}}] \text{ or } t_{\mathrm{TOP}} + t_{\mathrm{fill}} \in [0, 2t_{\mathrm{fill}}]$$

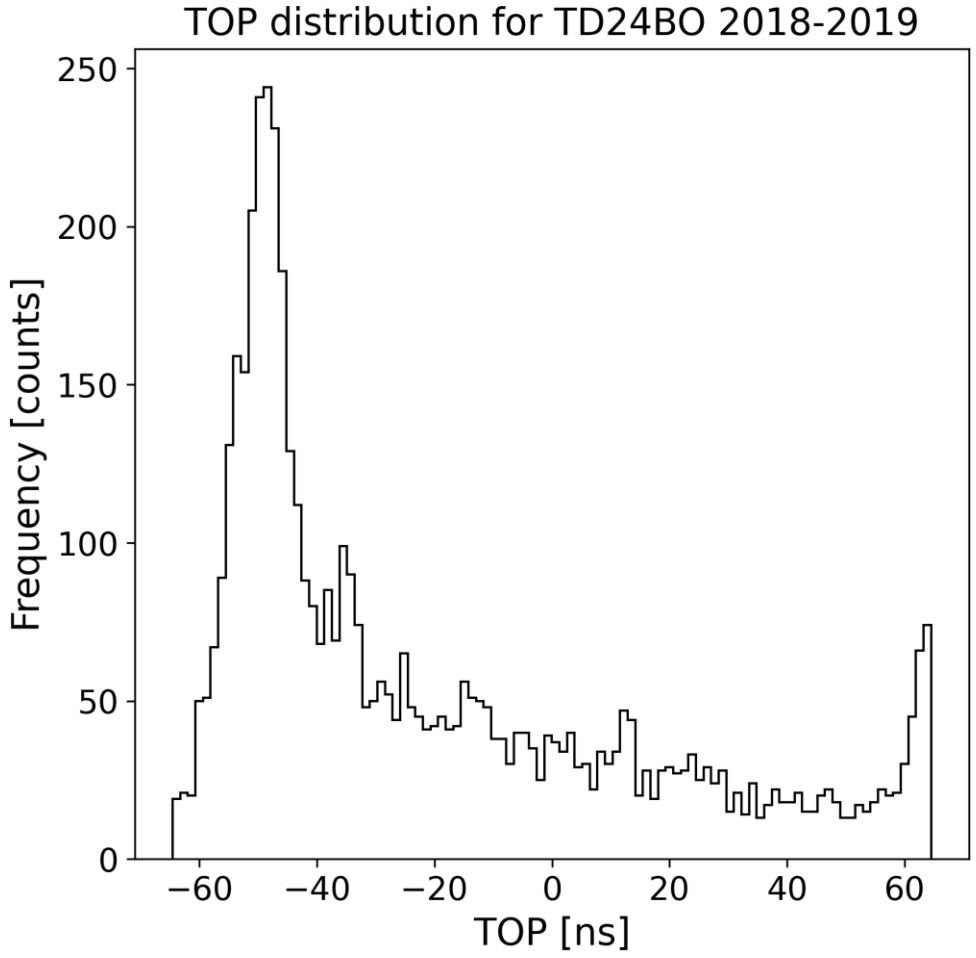
- If $|t_{TOP}| > t_{fill}$ then perhaps vacuum activity in hybrid or coupler

- Since we have same structure and waveguides, we can break vacuum and check this…

Time-of-Propagation filter (64.55ns, TD24)

$$t_{\mathrm{TOP}} \in [-t_{\mathrm{fill}}, t_{\mathrm{fill}}] \text{ or } t_{\mathrm{TOP}} + t_{\mathrm{fill}} \in [0, 2t_{\mathrm{fill}}]$$





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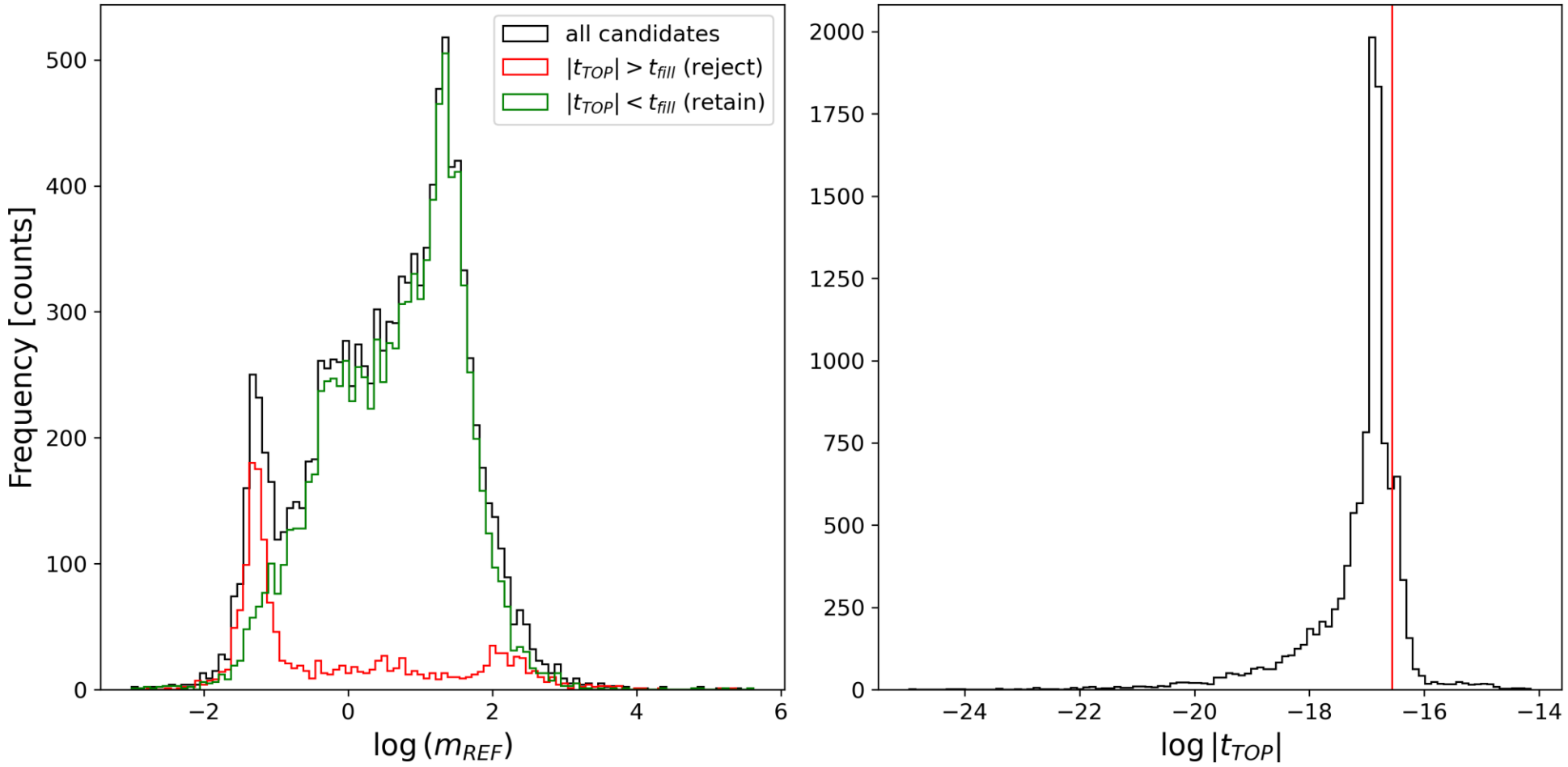

Take aways and To Dos

1. Continue to make this Dark Current analysis more precise
    1. Move from qualitative to measurement
2. Get distribution of arc ignition time
    1. Observe correlation with BD position
3. Get percentage of pulses with pre-bd activity
4. Plasma modelling of BD – c.f. Andrea Pallaia + Volker Ziemann
5. Implement circular buffer for pre-bd waveform storage
6. Fiber signals!