An experimental study of the Libera BLM applied to the proton-therapy linac LIGHT

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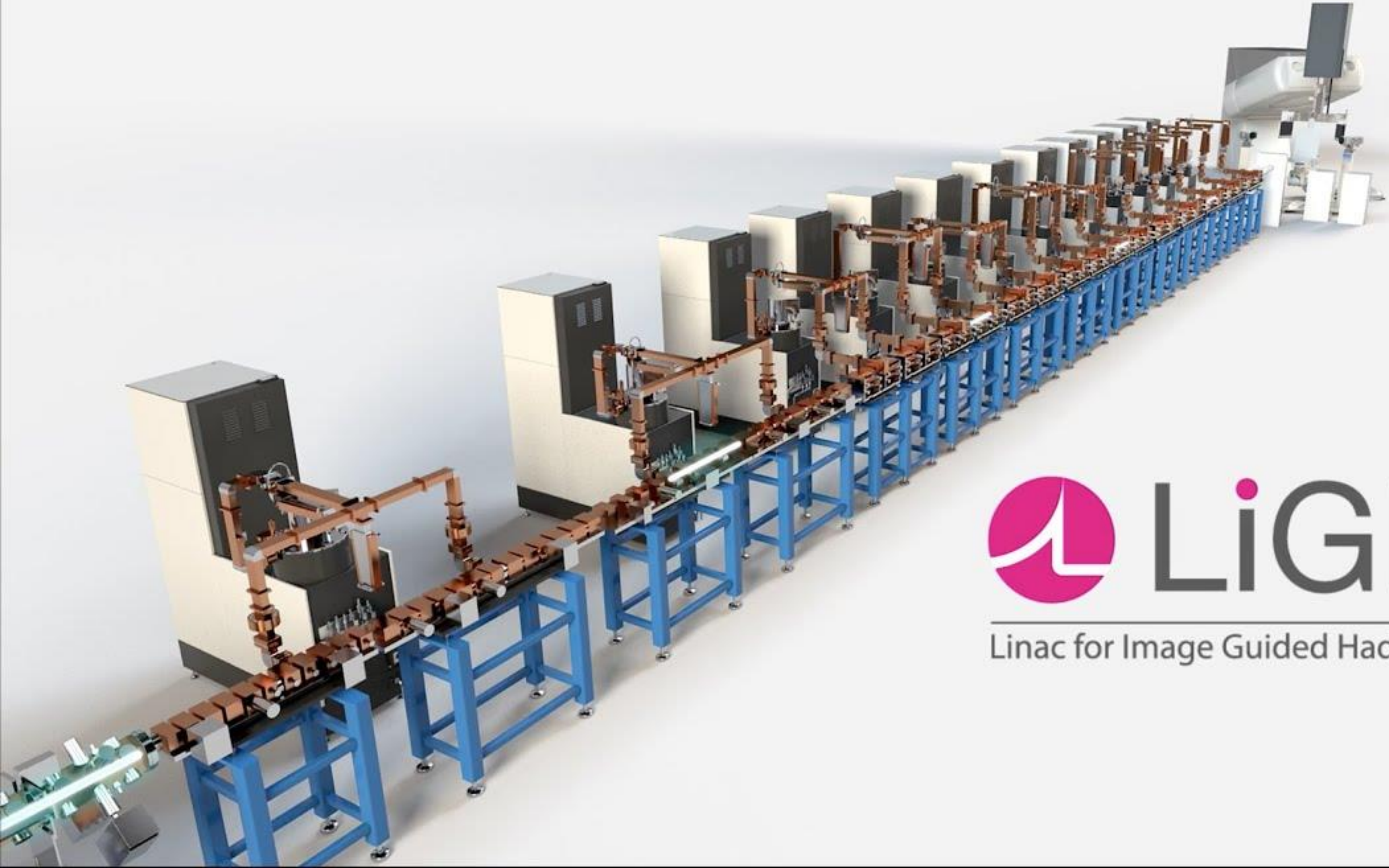
Democratising Proton Therapy

Overview

- LIGHT – Linac for Image Guided Hadron Therapy
- Libera BLM system
- BLM measurements of the x-ray background produced by the RF cavity
- Parasitic measurements next to a conditioning Side Coupled Drift Tube Linac (SCDTL)
- Measurements with a Cs-137 source next to a Coupled Cavity Linac (CCL)

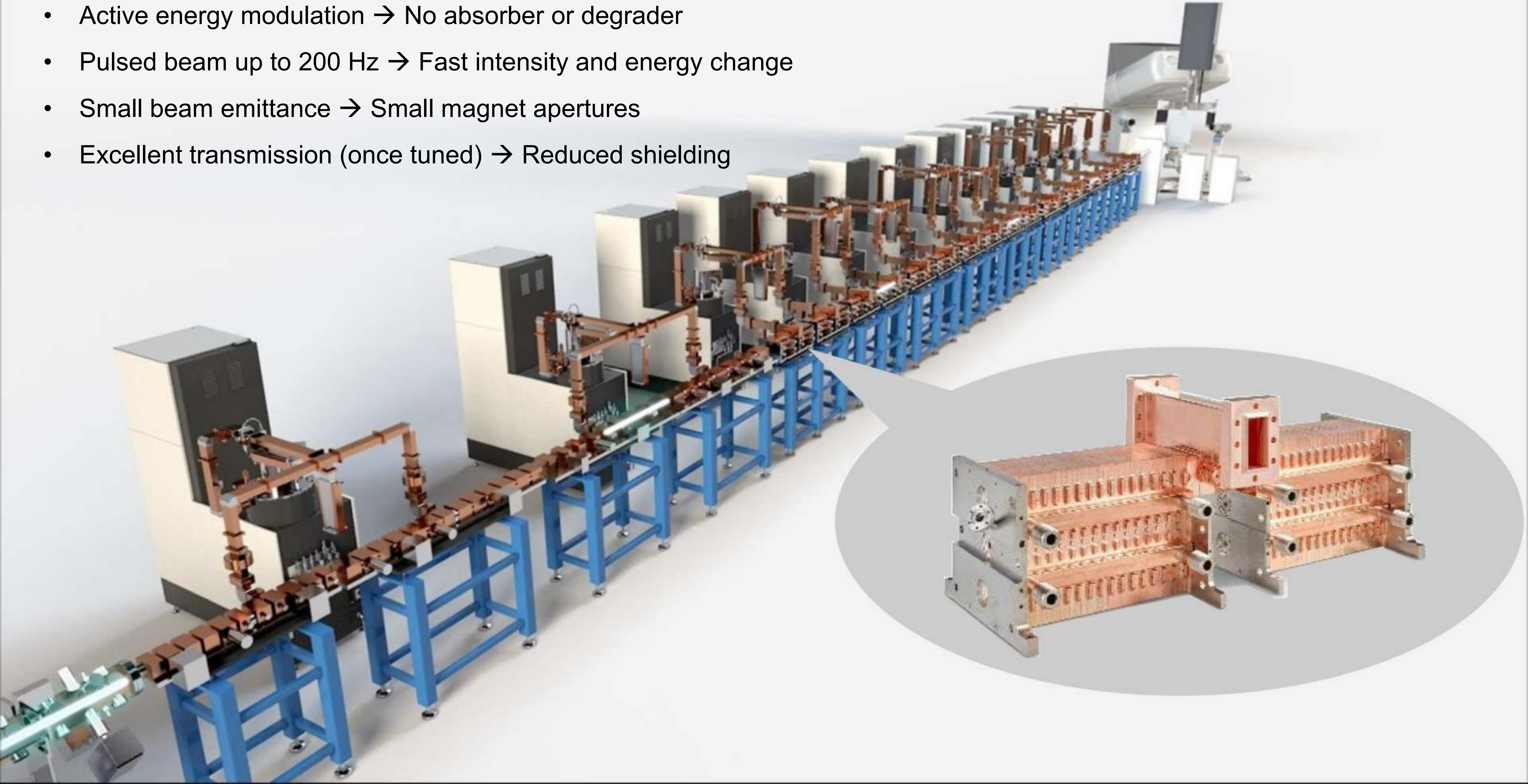


LiGHT

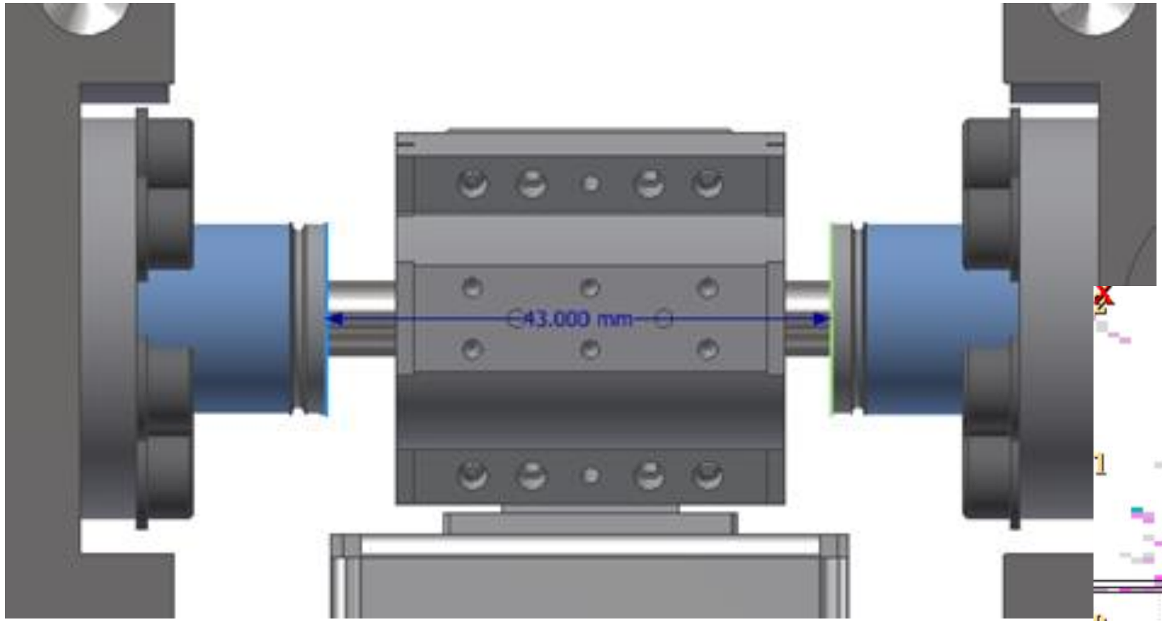
Linac for Image Guided Hadron Therapy

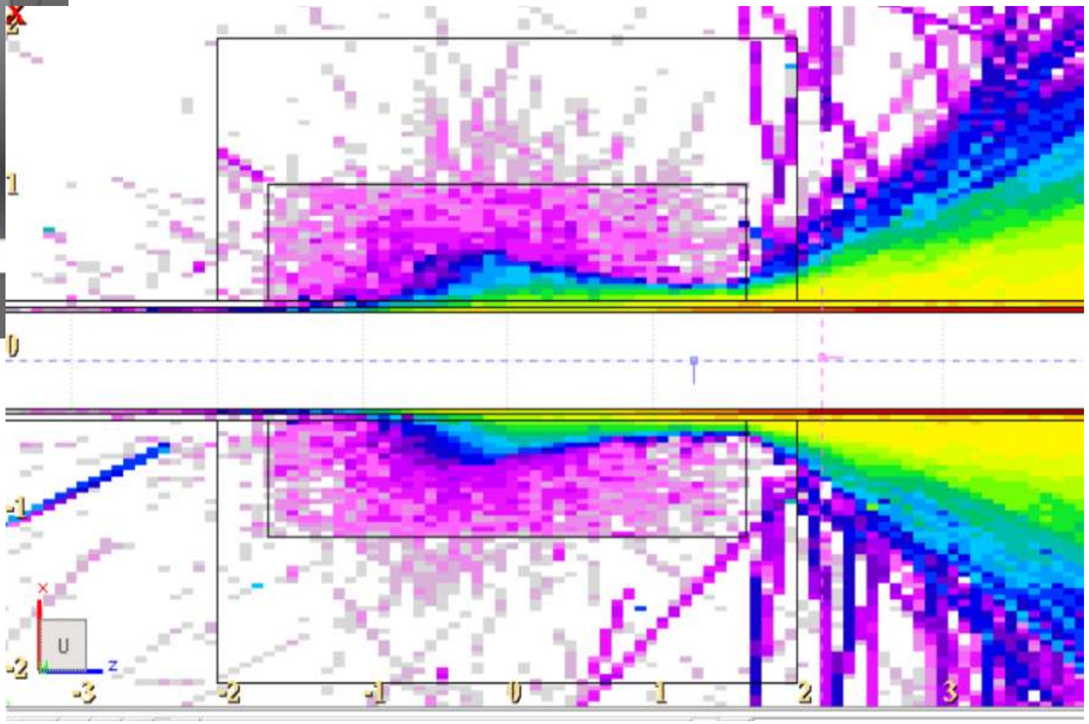
230 MeV Proton Linac:

- Active energy modulation → No absorber or degrader
- Pulsed beam up to 200 Hz → Fast intensity and energy change
- Small beam emittance → Small magnet apertures
- Excellent transmission (once tuned) → Reduced shielding



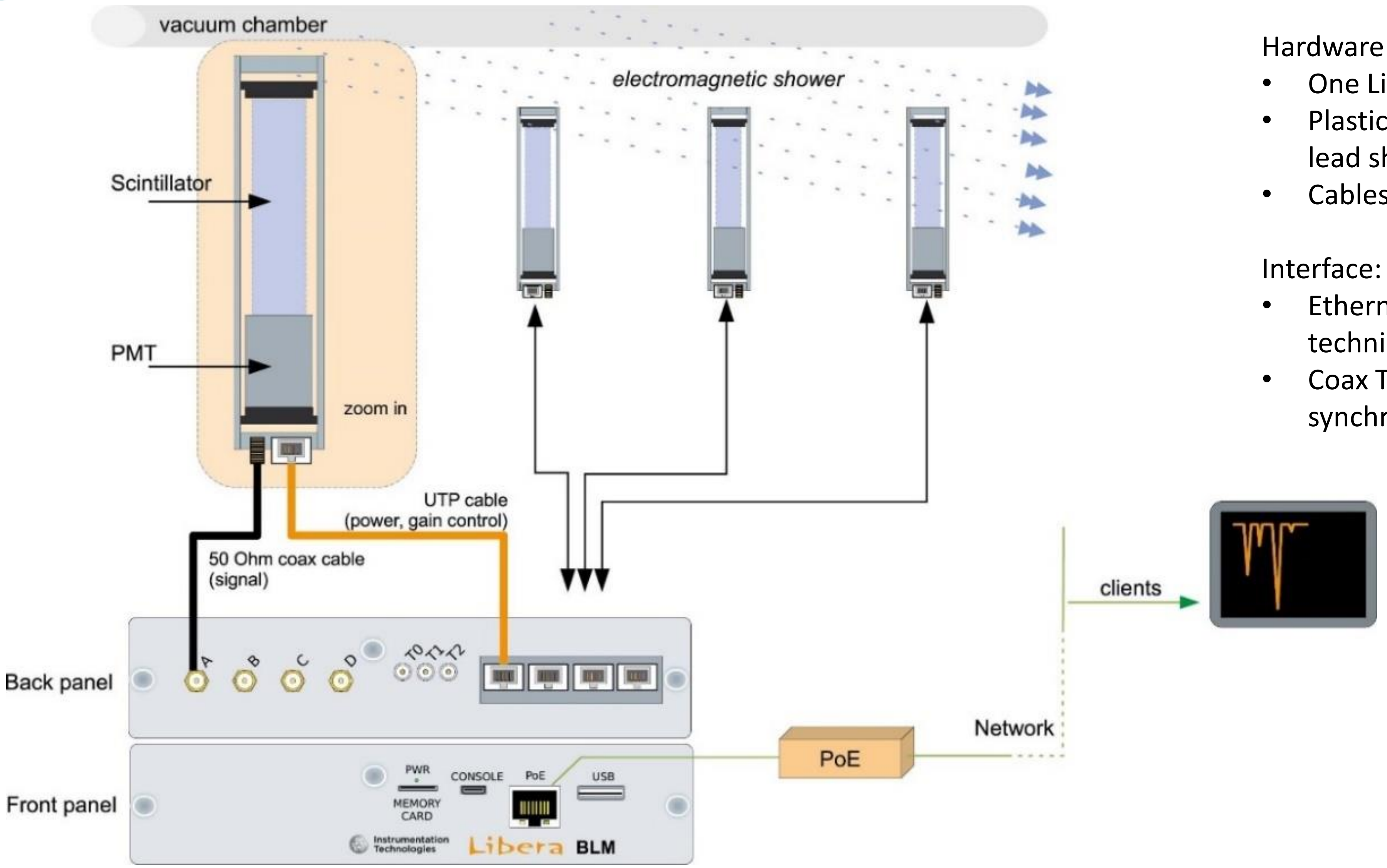
Expected position of Beam Losses





- Beam aperture restrictions make losses most likely between tanks (Beam pipe diameter is 6mm).
- FLUKA simulations estimate loss map after PMQs.
- Gaps between tanks as small as 20 mm.

Libera BLM System Overview



Hardware available:

- One Libera BLM
- Plastic Scintillator coupled to PMT + lead shielding
- Cables

Interface:

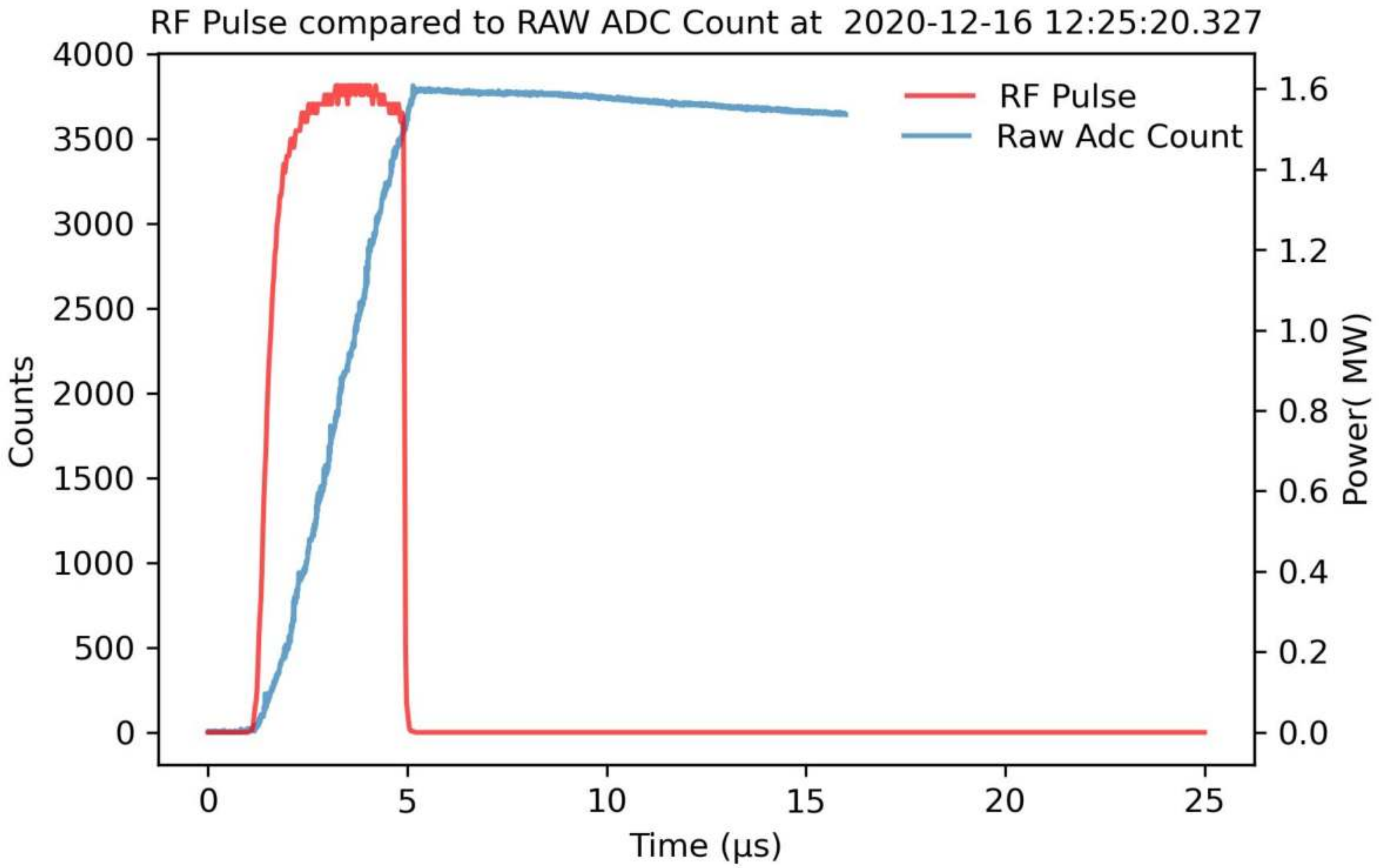
- Ethernet cable in the accelerator technical network via a PoE switch
- Coax Trigger from timing, synchronized with RF events

Initial Tests at Daresbury

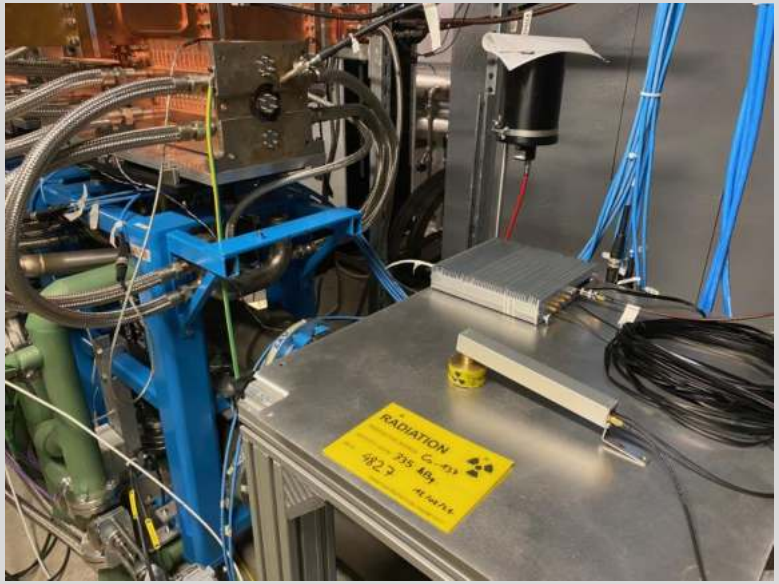
- Parasitic measurements during SCDTL cavity conditioning
- Measurement of sensitivity to x-rays from RF
- Learning period on how to use it
    - A Few technical issues
    - Difficult access to the room

RF Data From DIS (High Impedance)

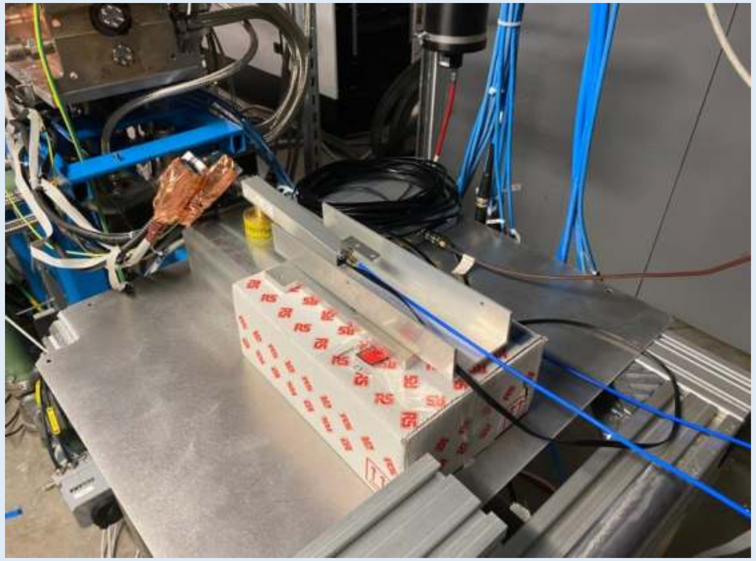
We could clearly see the effect of the RF pulse in the BLM (RF → field emitted electrons → X-rays)
Red Pulses from RF pickup. Blue pulses from BLM.



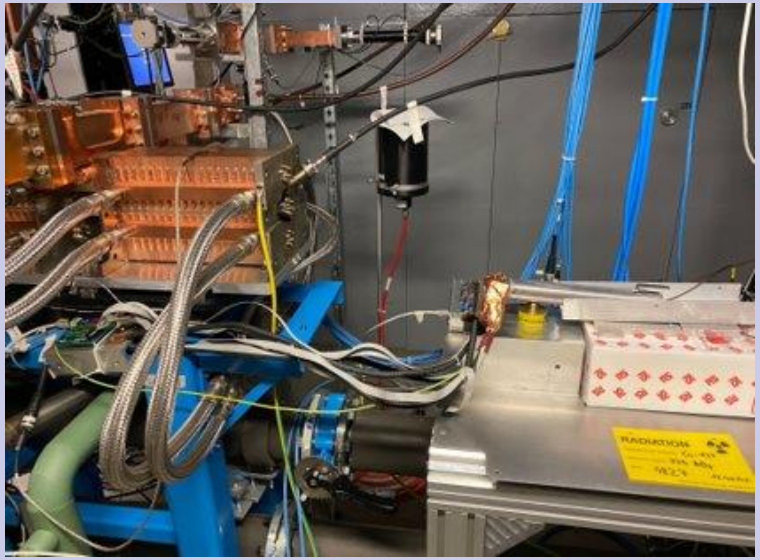
Setup#1 at CERN P2: downstream CCL module 2



First data with Cs-137 source (335kBq, dose rate 0.2 μSv/h at 40 cm) **and RF. Scintillator at contact, no shielding**

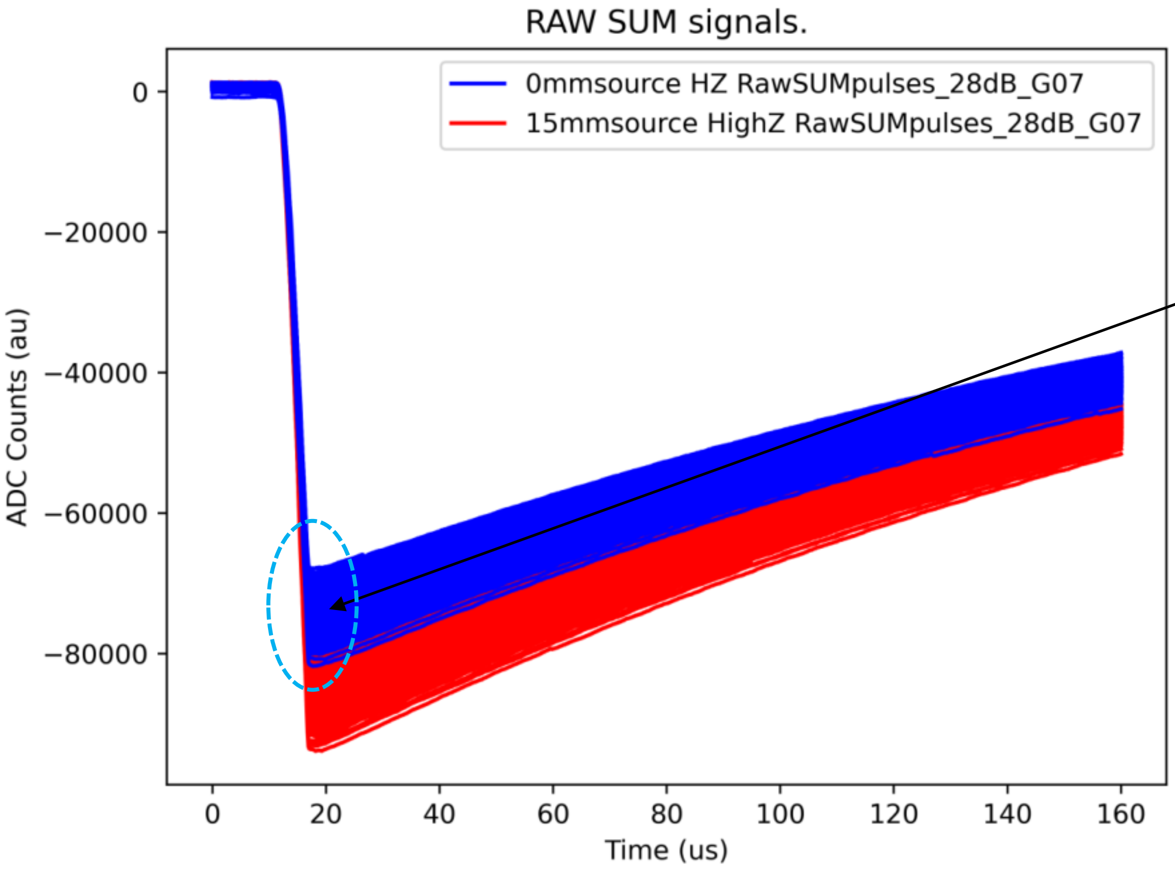


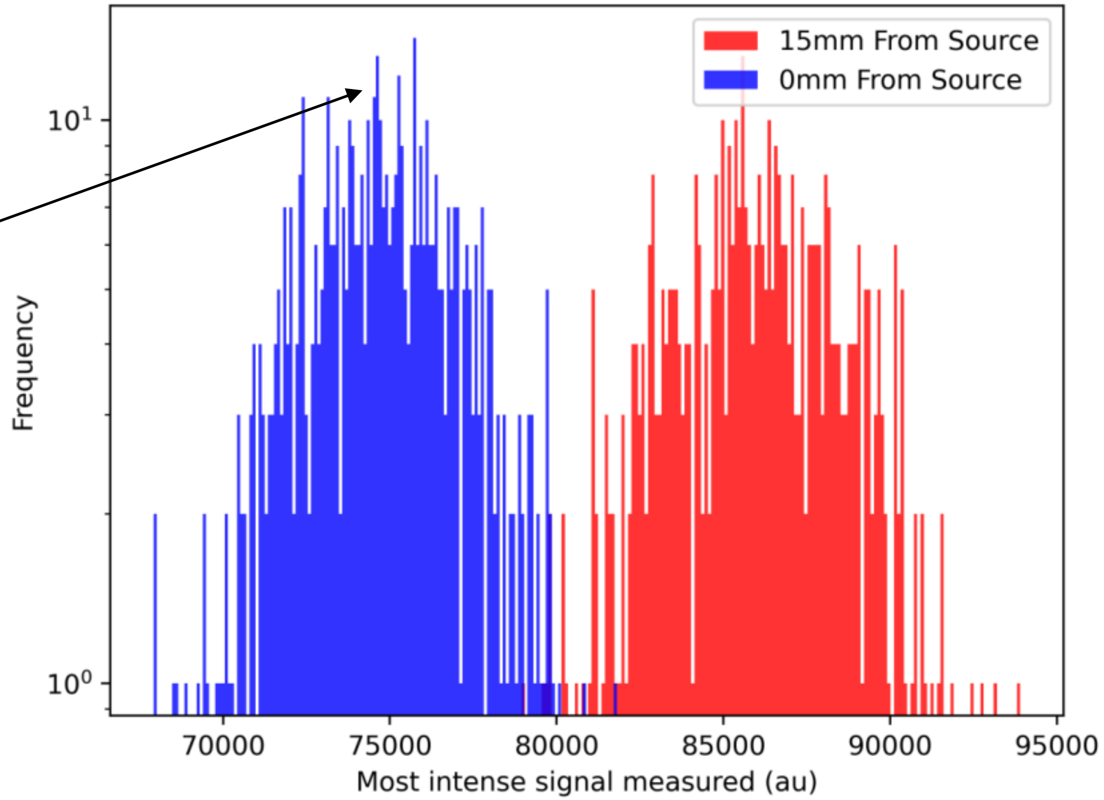
Source and detector raised to be approx in line with cavity



Scintillator with shielding on, at contact with the source

Comparison Of Pulse Shapes at different distances from source with BLM set in high impedance, Setup#1



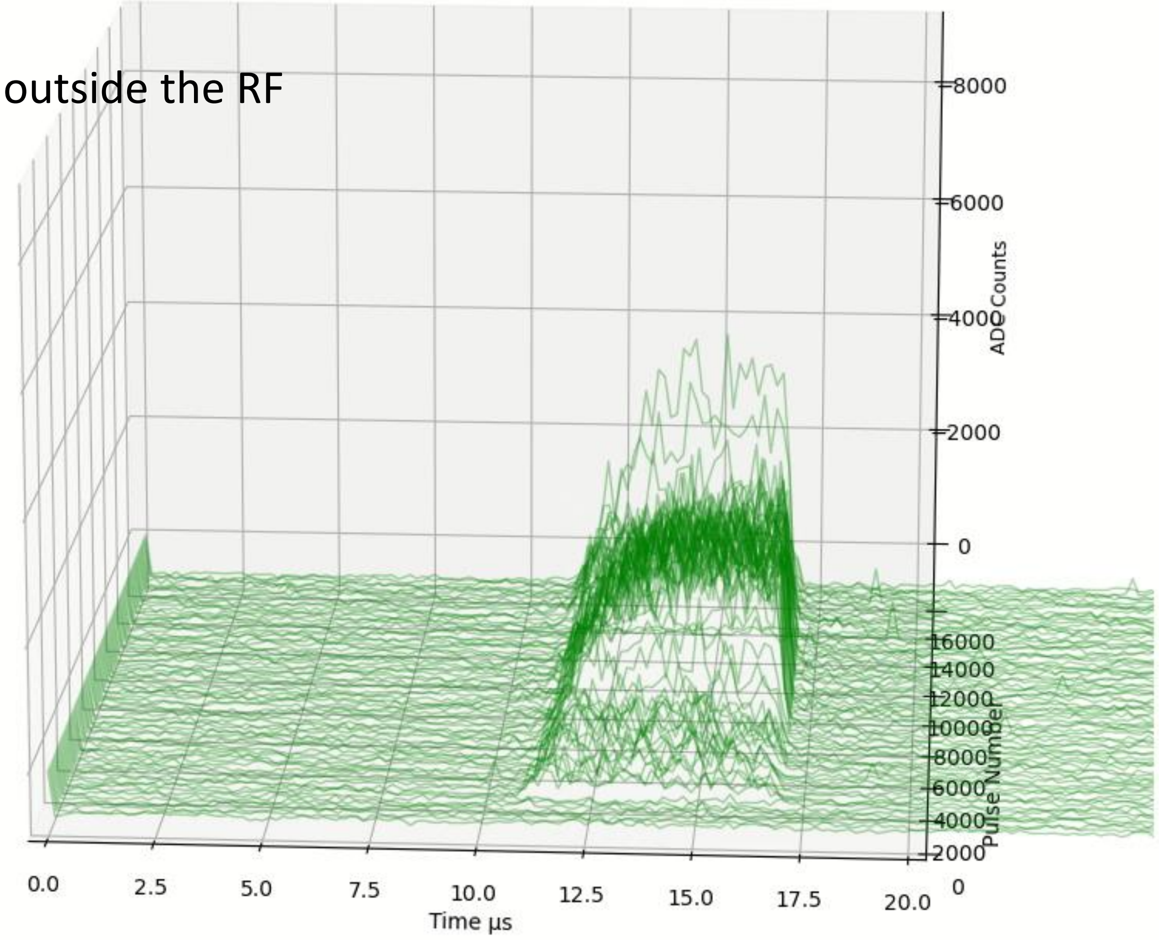


Noshielding, RFnominal in CCL1 and 2, at contact (RED) and raised 15mm (BLUE) from the source. More X-rays collected when raising the detector. **No clear signal from source radiation**

Waterfall Plots (RF Scan) (Unshielded), Setup#1

- 50Ohm coupling allows X-rays RF pulse detection
- RF in CCL2 set to 0% and increased to 90%

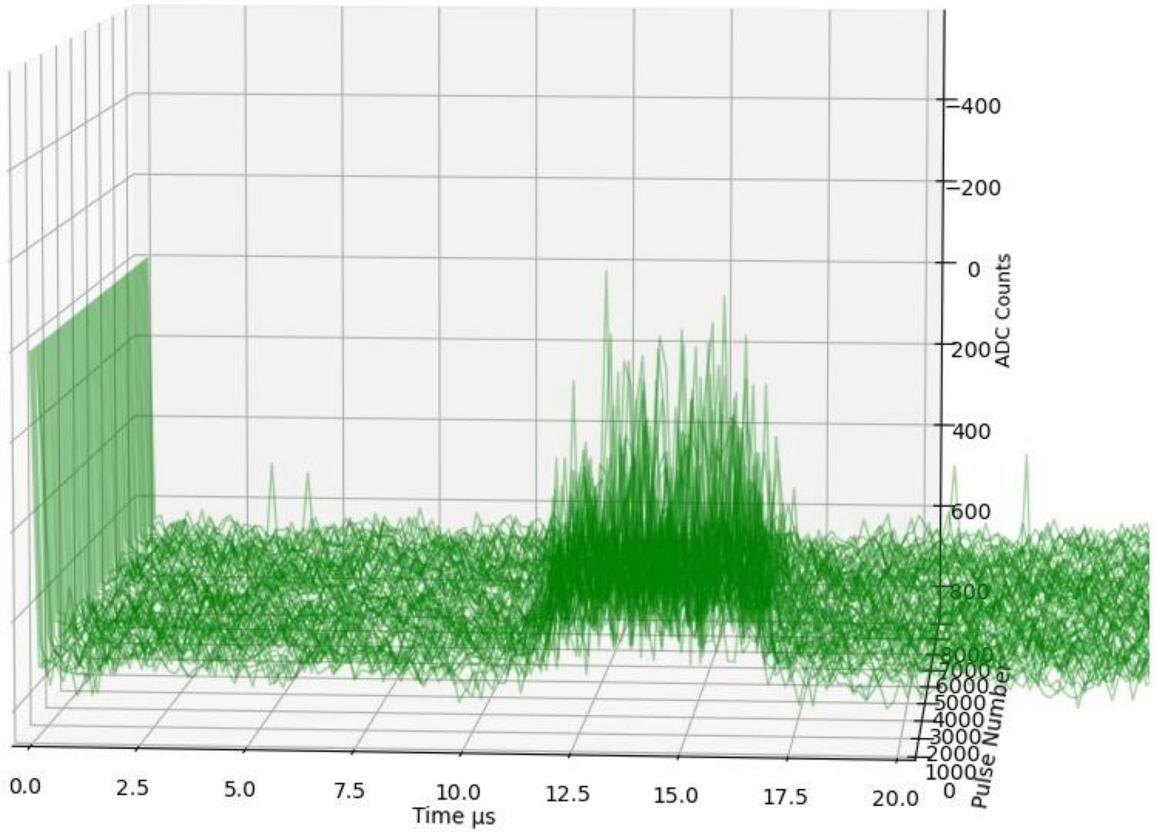
- Few gammas from source observed outside the RF pulse



20210324_BLM_NoShielding_0mm_50Ohm_RFscan

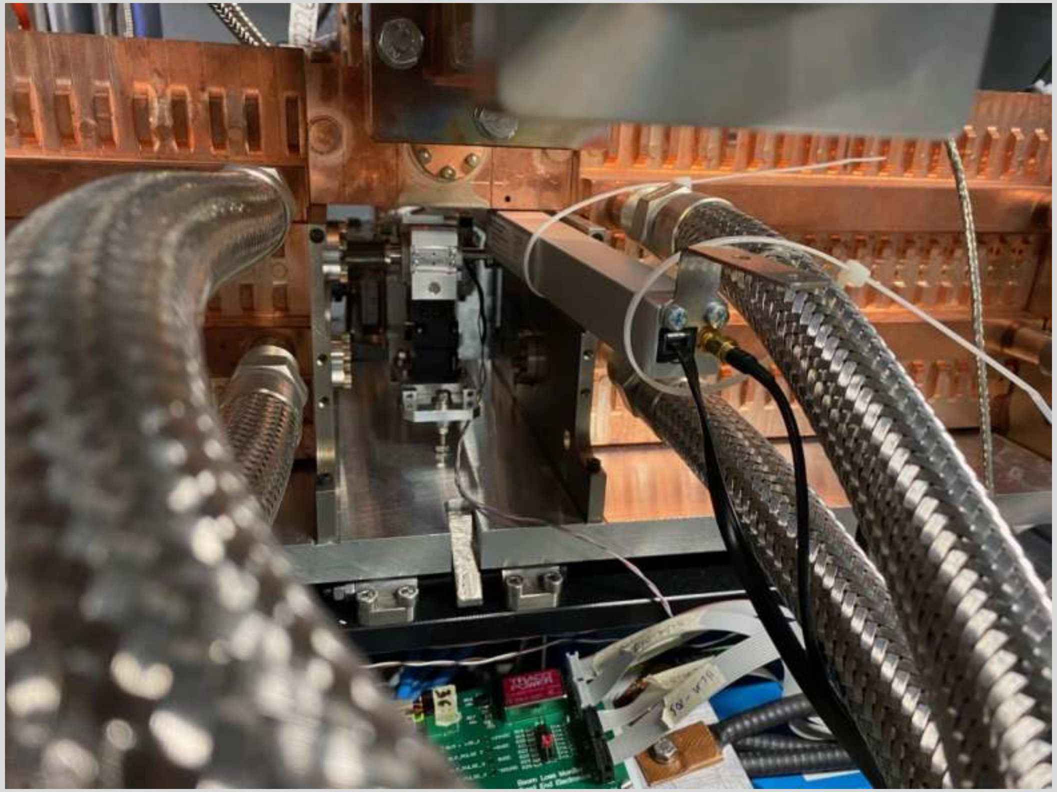
Waterfall Plots (RF Scan) Detector Shielded, Setup#1

- shielding attenuates the x rays more than the gamma → gamma events more visible
- However worse SNR



BLM_Shielding_0mm_50Ohm_RFscan Sum

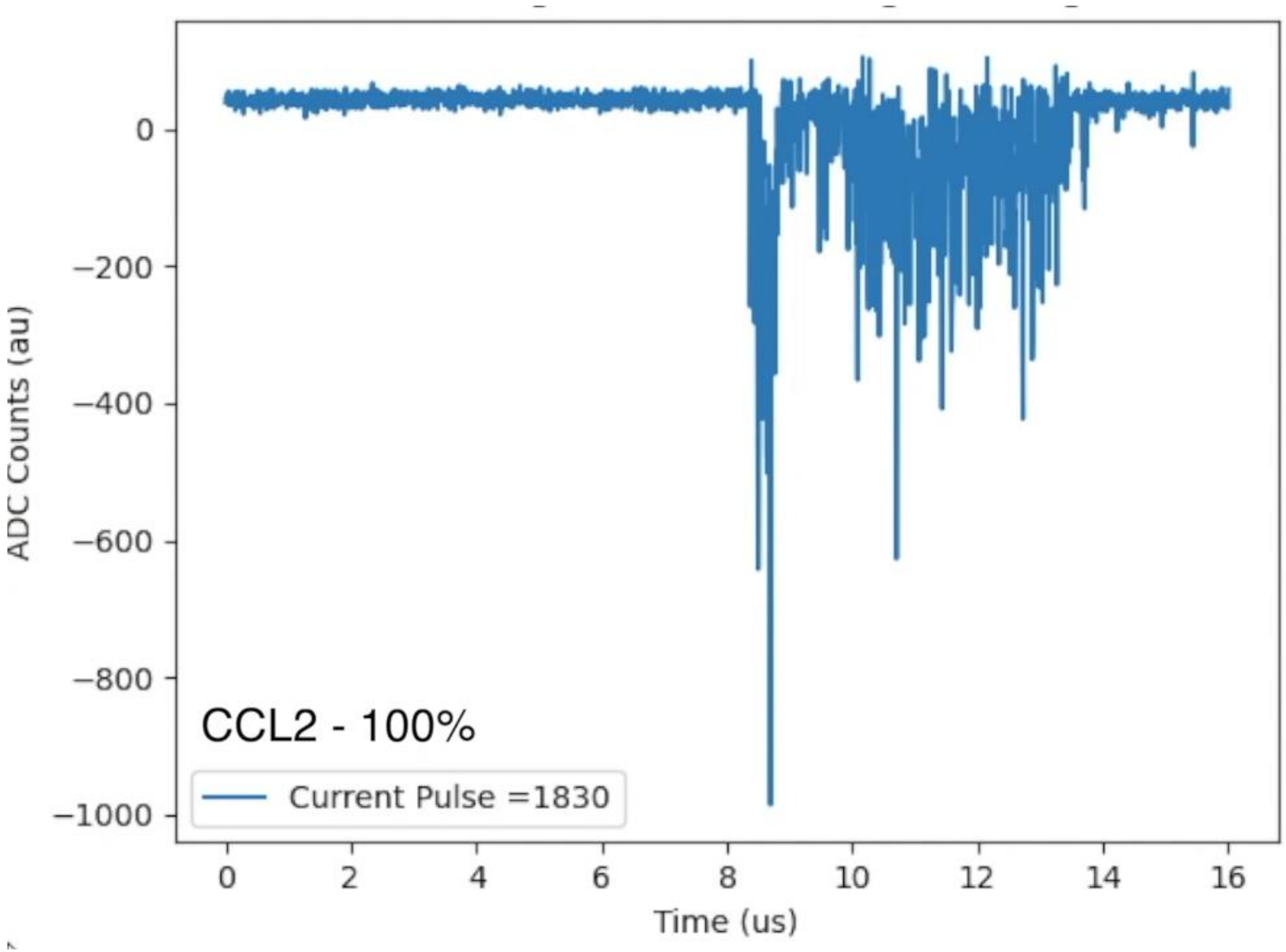
Setup#2 at CERN P2: between tank 1 and 2 of CCL module 2



No source, only RF, Scintillator in its real position, no shielding

Same with shielding

Scanning through RF viewed as a 2D Plot evolving over time (no source)



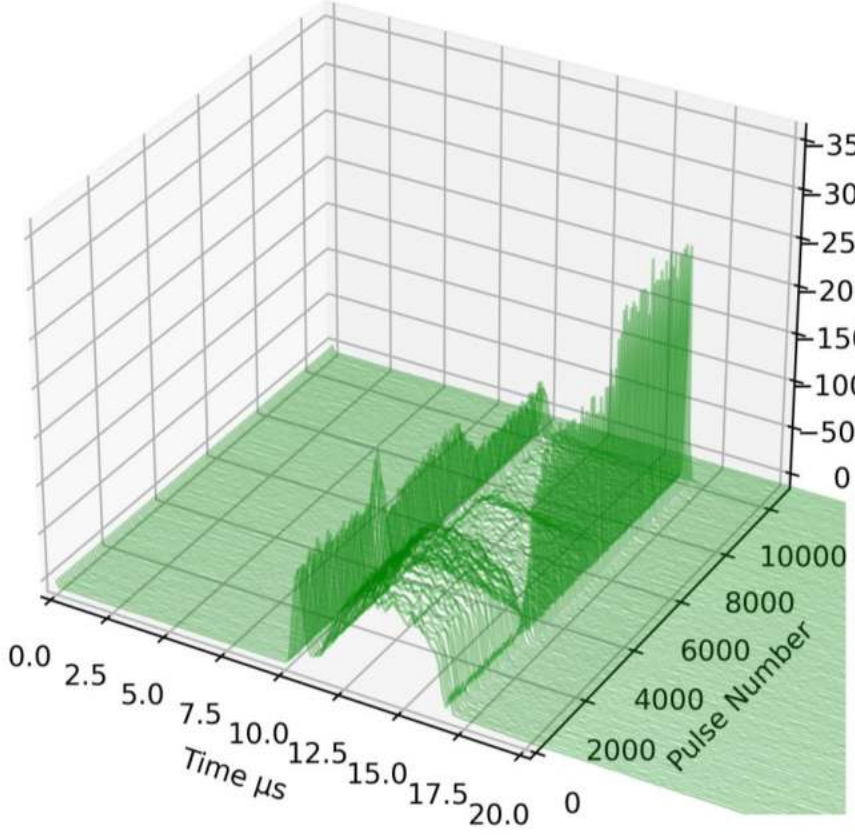
BLM_Noshielding_nosource_50Ohm_RFscan

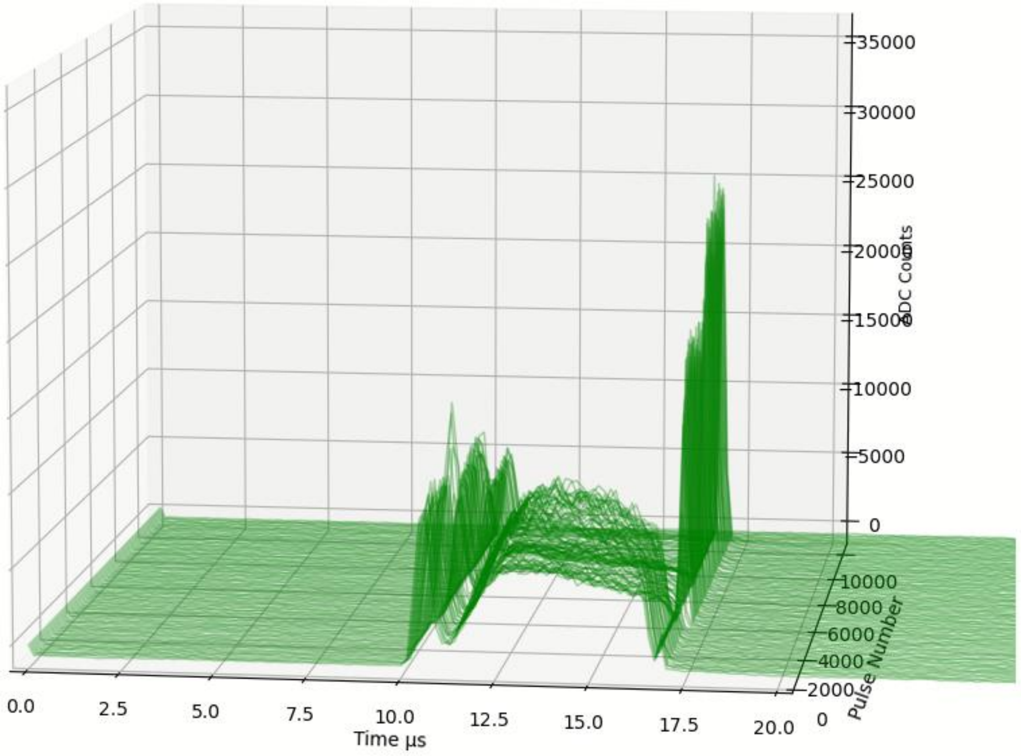
- Only RF, no rad source

- Two spikes show the beginning and end of RF pulse as the cavity charges and discharges.
- Correlated with reflected power.
- Can only see these spikes when BLM is placed in the middle of the cavity (Setup#2).

Waterfall Plots (RF Scan) Unshielded, Setup#2

Pulse 0 – 100% RF Power in CCL2
Pulse 5000 90% RF Power in CCL2
Pulse 7000 80% RF Power in CCL2 – From ~80% centre of pulse is close to 0 intensity.
Pulse 11000 0% Power in CCL2 (Hard to distinguish).

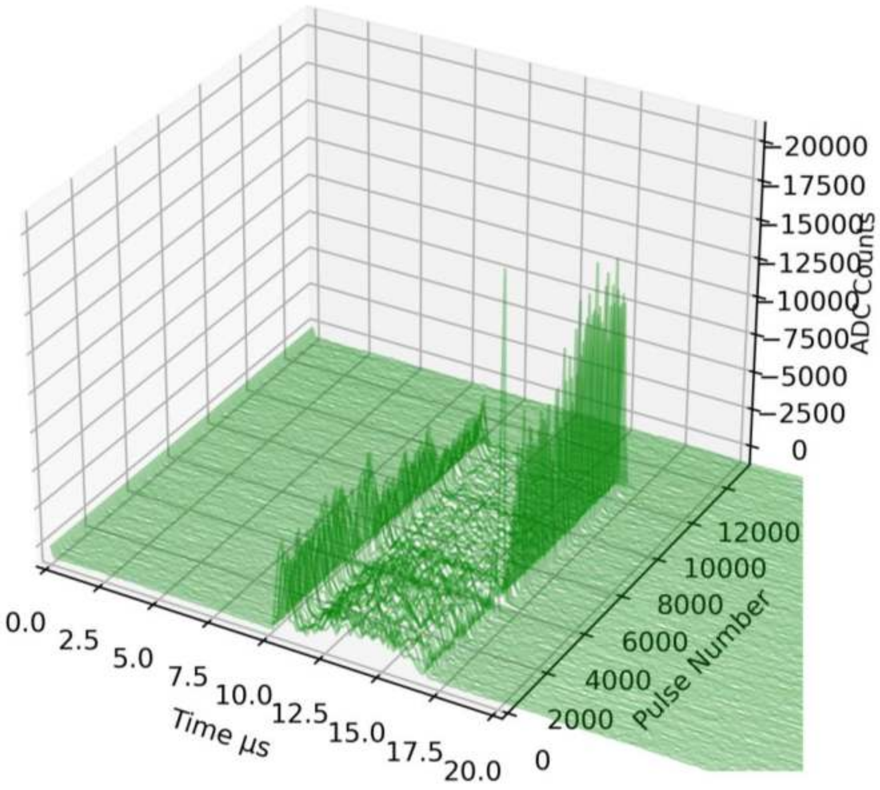


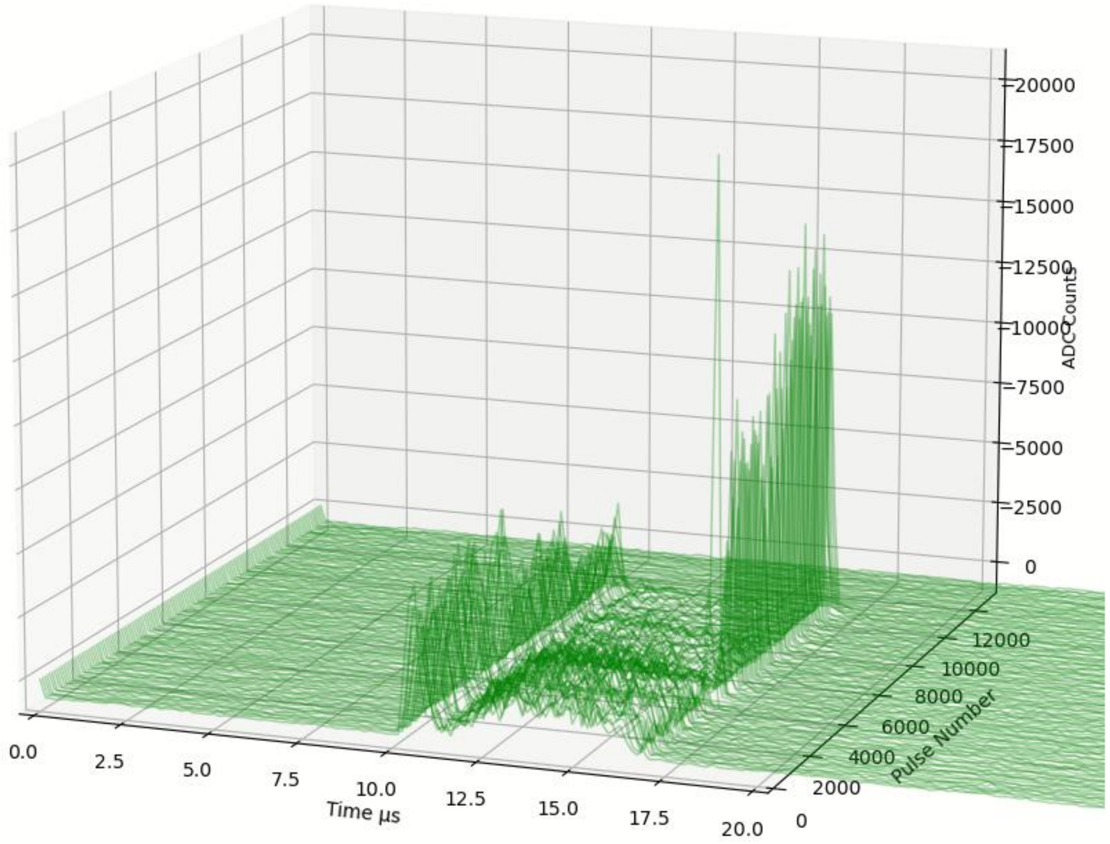


BLM_Noshielding_nosource_50Ohm_RFscan Sum

Waterfall Plots (RF Scan) Shielded, Setup#2

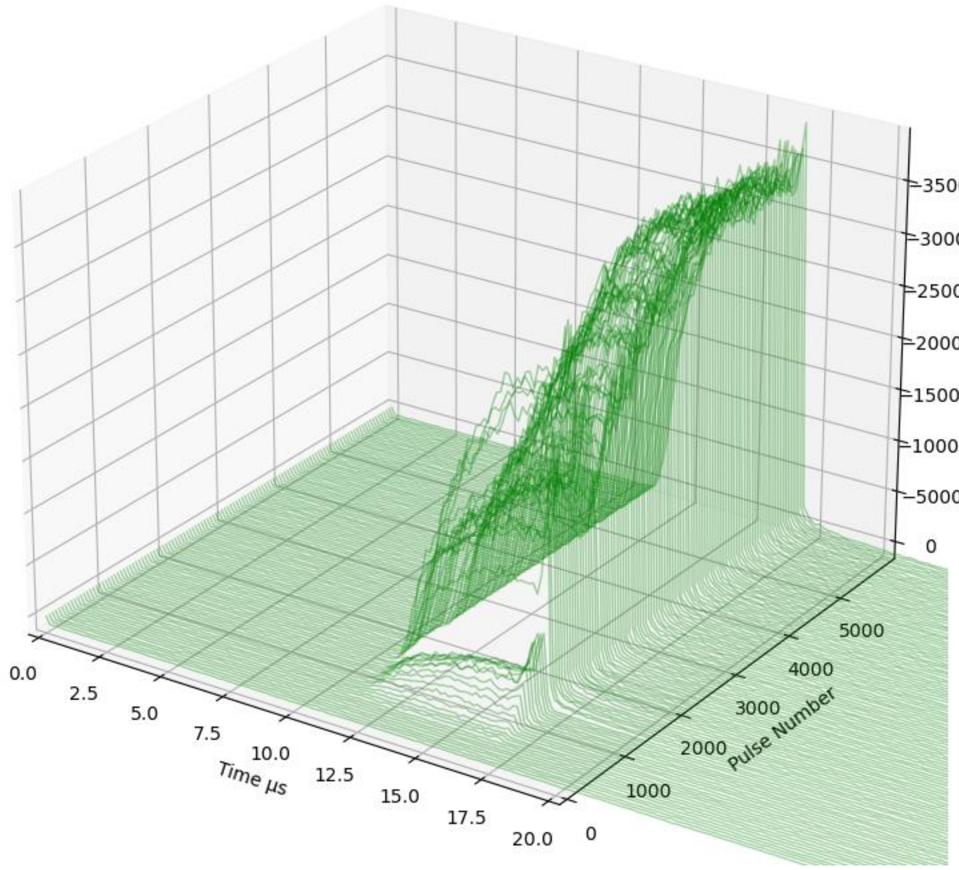
Same as previous set up but detector now shielded.
Observed decrease in amplitude by roughly a factor of 2.



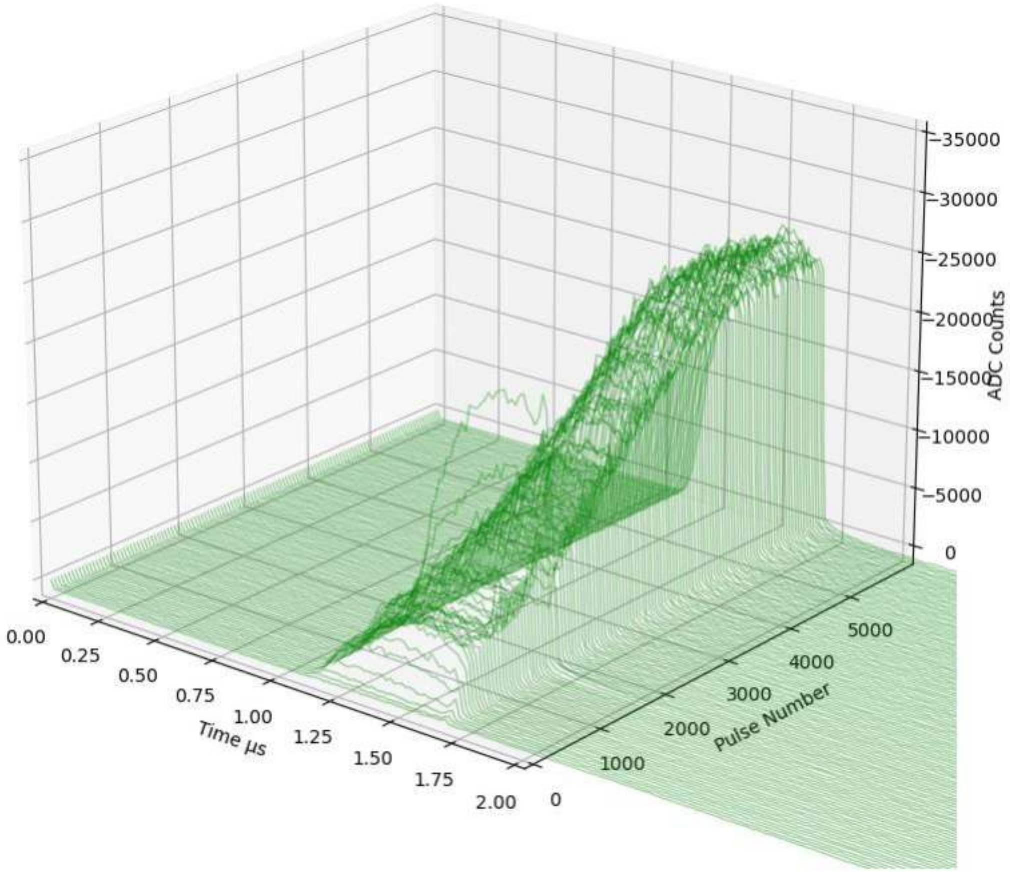


20210324_BLM_Shielding_nosource_50Ohm_RFscan

BLM placed at different azimuthal angles – RF Scan

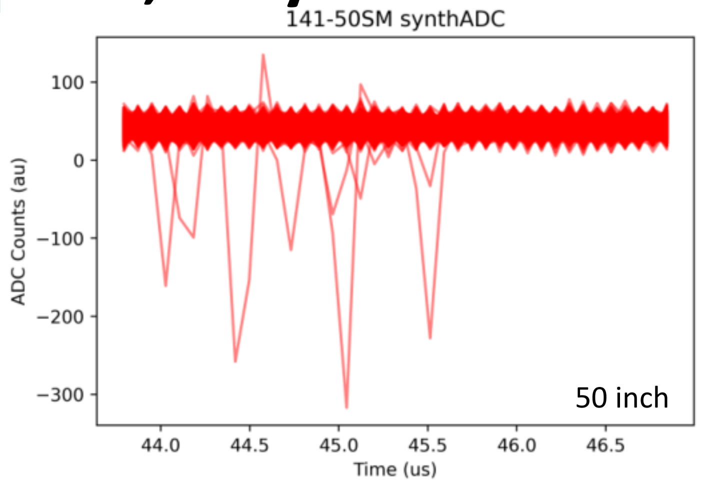


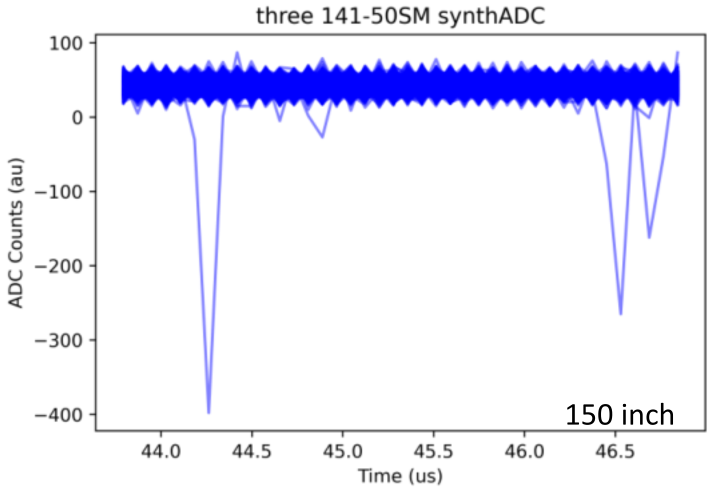
Top

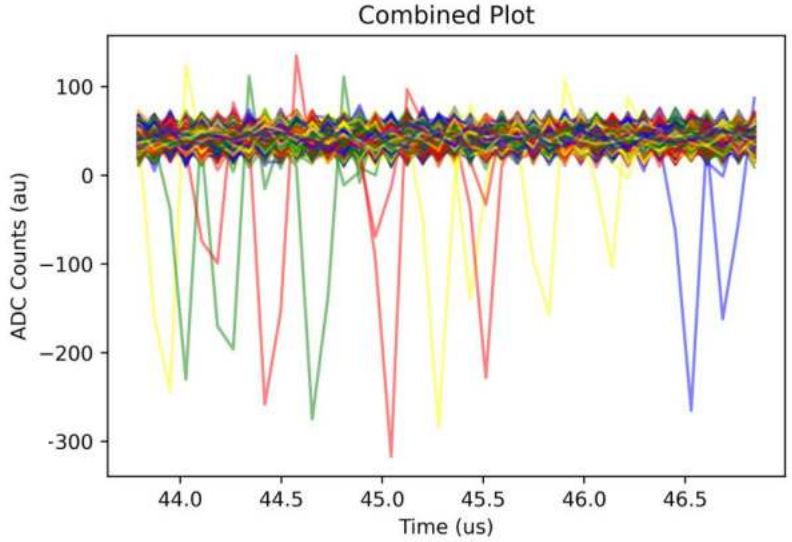


Left

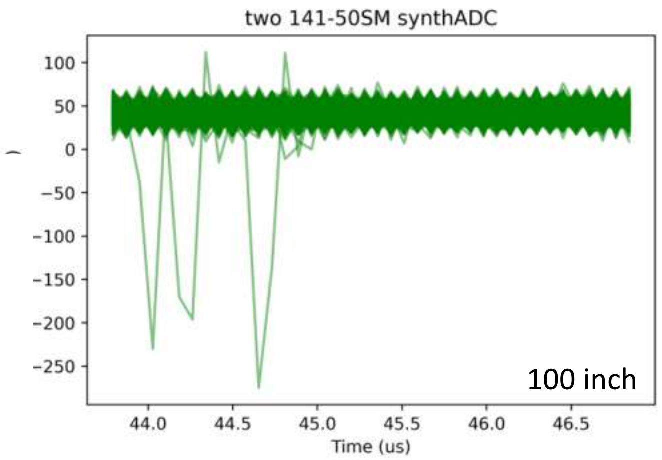
Comparing gamma ray pulse shape at different co-axial cable lengths, Setup#1, **no RF, only rad source**

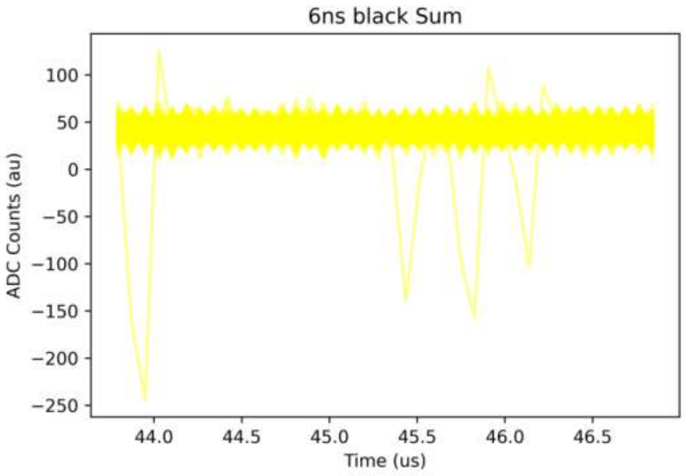




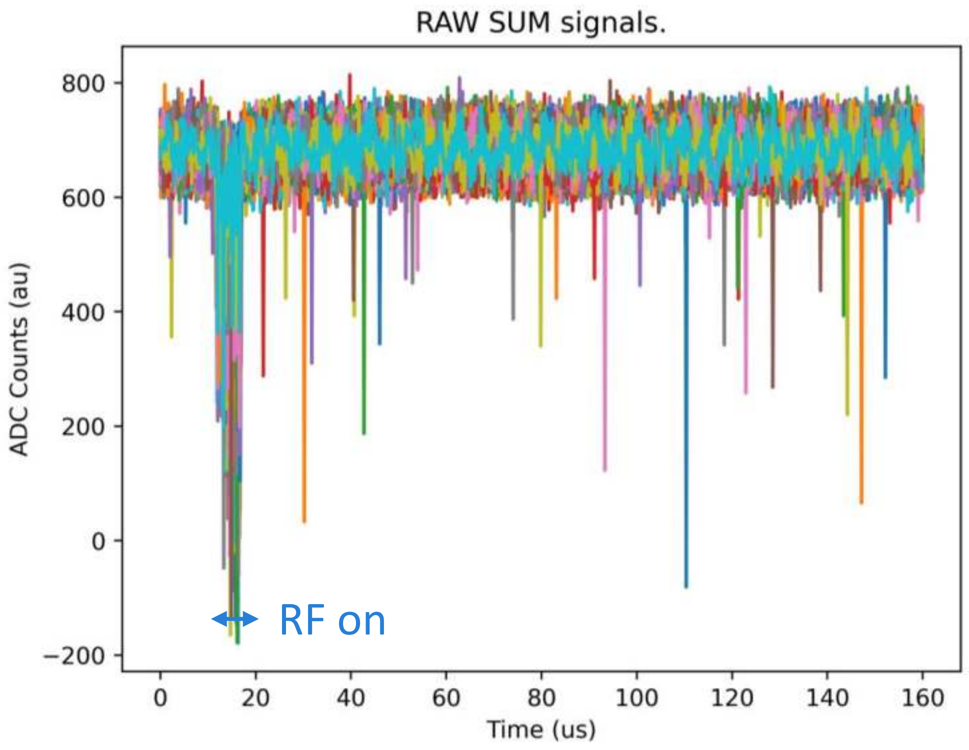


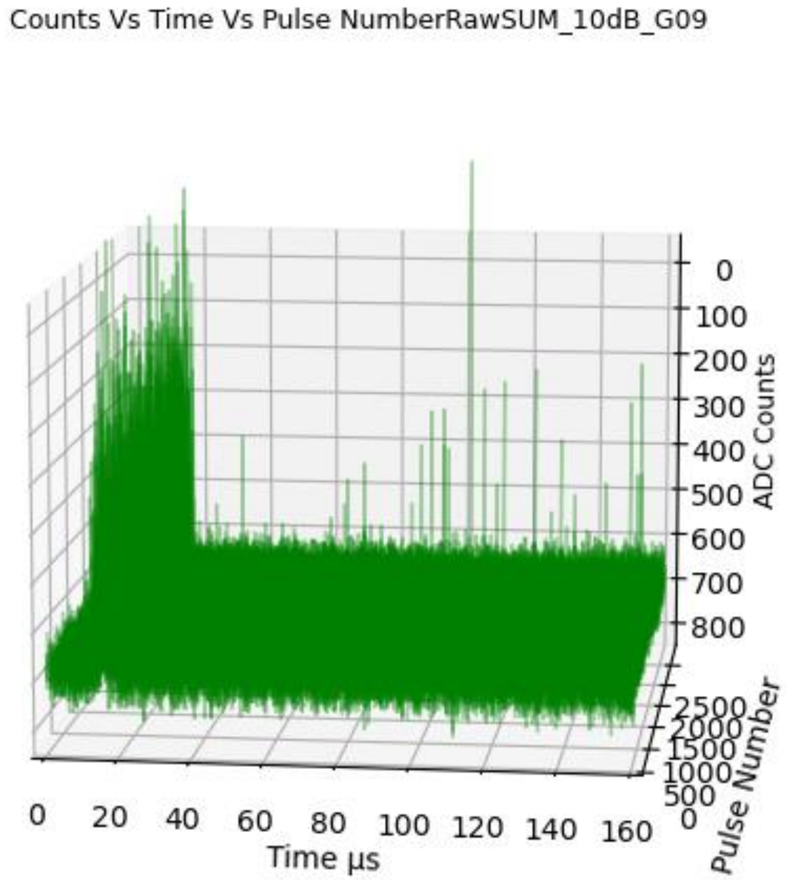
Gamma event lasts ~50 ns





RF ON, 0mm From Source With Shielding, Setup#1





- SUM signals show the sum of 16 ADC bins with time. In the time where RF is off, gammas can be seen clearly!
- **One possibility is to measure the radiation from activation *outside* of the RF pulse.**
- **Advantage is significantly improved Signal/background**
- **Disadvantage is delayed response of tunings.**

Conclusions

- It is not possible to distinguish the radiation emitted from the Cs-137 source from the RF pulse induced X-rays in any BLM configuration (Shielded or Unshielded, HZ or 50Hz) when RF power in a cavity is >80%.

- Outside of the RF pulse, gammas from the source can be seen clearly.

- Fluka simulations estimate the signal from beam losses to be ~25% of the RF signal intensity. It may be possible to detect beam losses **inside the RF pulse.**

- The activation of the beamline could be used to detect beam losses by measuring **outside of the RF pulse**. This method significantly improves Signal/background **but adds a delay between tuning and detecting losses.**

- Cable length **up to 4 m** (between scint and Libera) has no effect on bandwidth.