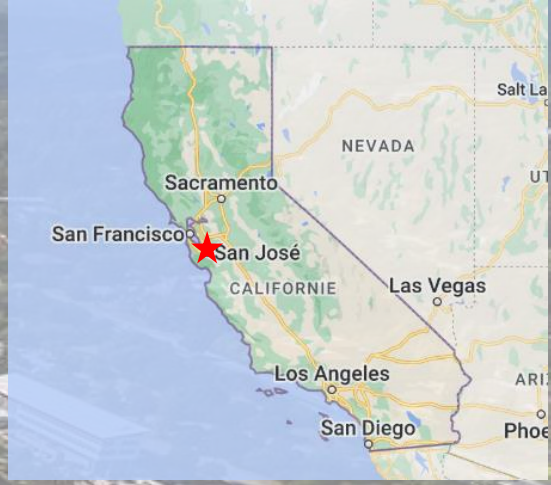

Early field emission detection at SLAC

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U.S. DEPARTMENT OF ENERGY
Office of Science

SLAC NATIONAL ACCELERATOR LABORATORY

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- Radiation monitoring devices
  - Cherenkov fibers
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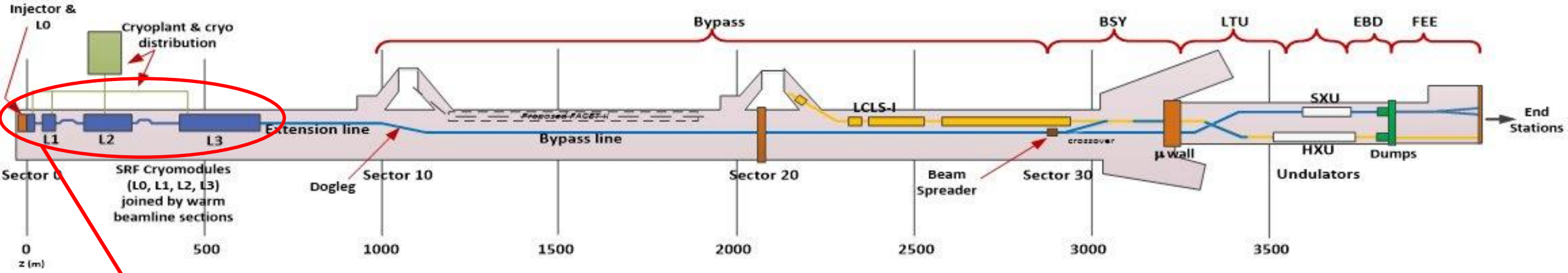
  - Thermo Fisher FHT190 (ion chambers) and Average Current Monitors
  - Area Monitoring Systems, Beam Shut-Off Ion Chambers,…
- Field emission at SLAC and Monte-Carlo models
- Measurement results during commissioning phases
  - All cryomodule RF turned ON
  - Beam sent to diagnostic dump
- Conclusions

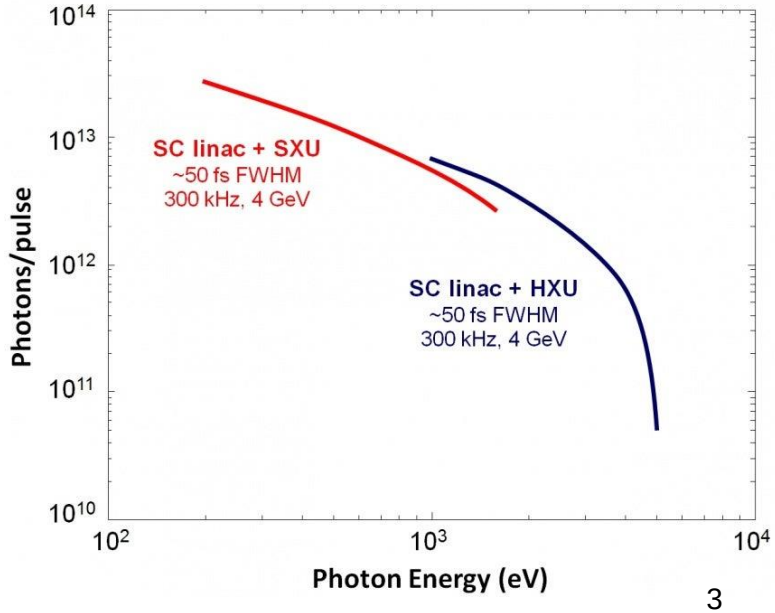
LCLS-II & description



35+2(1/2) Cryomodules for acceleration made of eight TESLA type 1.3 GHz cavities

Electron side	
Energy [GeV]	4.5
Max repetition rate [kHz]	930
Bunch charge [pC]	20-300
Max Power [kW]	120

Photon side	
Photon energy [keV]	0.2 to 5
Repetition rate [MHz]	until 1
Pulse duration [fs]	1 to 100



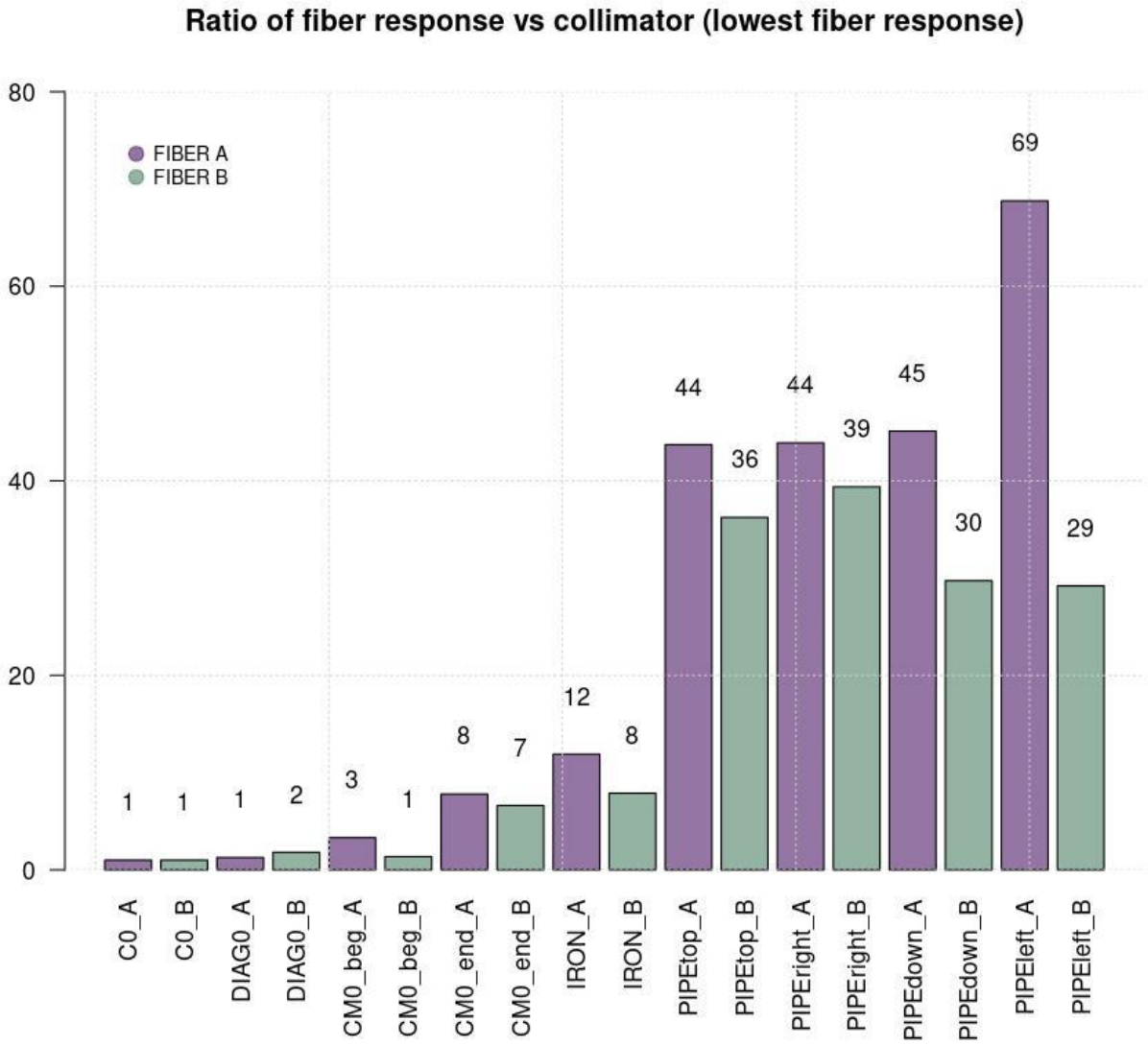
Cherenkov fiber

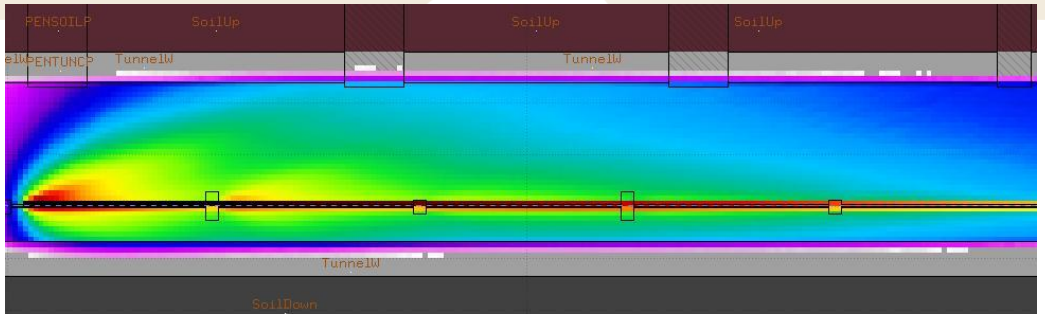
[Phys Rev. Acc. & Beams 23, 082802 (2020)]

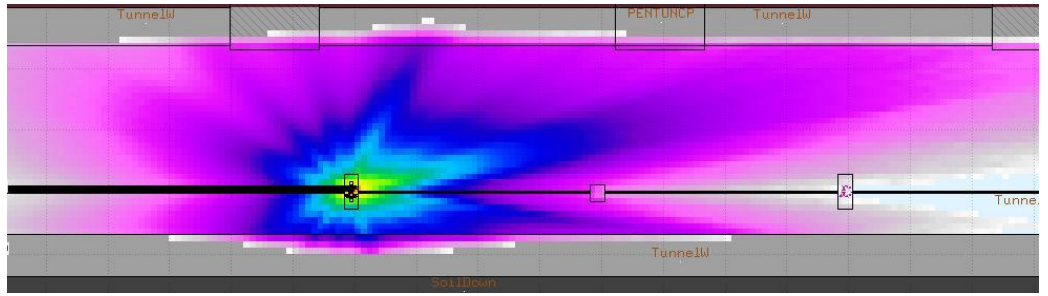
- Part of the machine protection system and **safety system**
- 49 overlapping fibers in the LINAC, ~200 m long (attenuation)
- Charged particles produce Cherenkov light, a fraction of which will travel to the Photomultiplier at the downbeam end
- Fast response time of few tenth of microseconds
- Signal degradation below 10 MeV
- Loss points can be localized by measuring arrival time vs. beam pulse (for beam losses only)
- Response ‘fields’ for BLMs can be simulated with FLUKA Monte Carlo code [JACoW-IPAC2019-THPRB102]

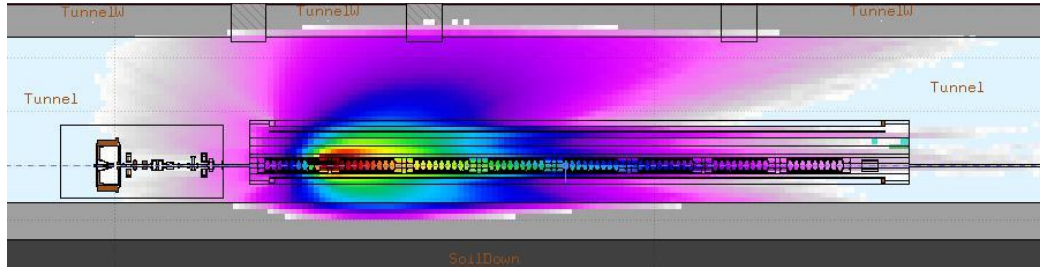
Cherenkov fiber

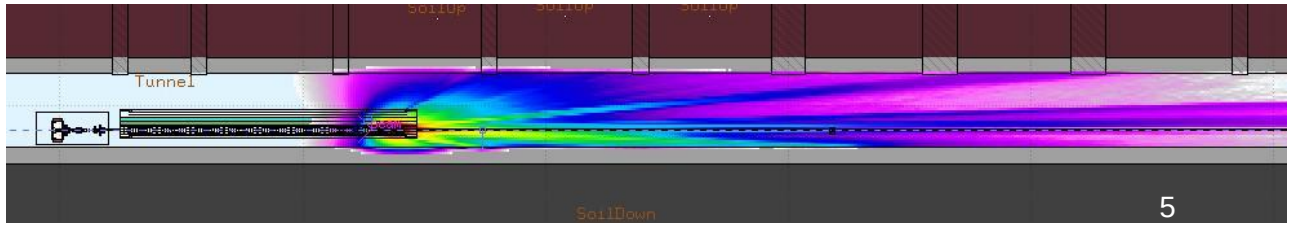
Unnormalized radiation fields









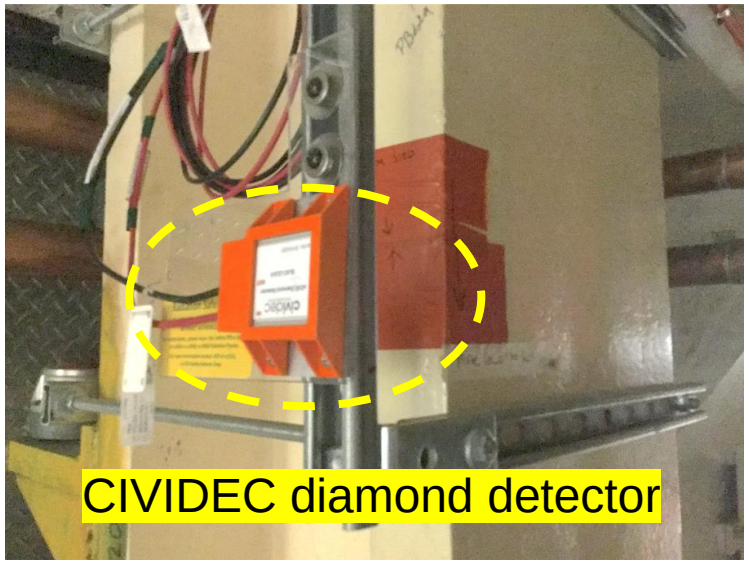


CIVIDEC diamond detector

- CIVDEC diamond detectors can be
  - Part of the Machine Protection System
  - Part of the safety system
- 70 CIVIDEC in the LINAC
- Synthetic diamond detector. Lost energy in the detector creates an electron-hole pair (few ns to reach electrodes)
- 3 types of detectors:
  - Single crystal
  - Polycrystalline
  - High radiation polycrystalline (lower sensitivity)

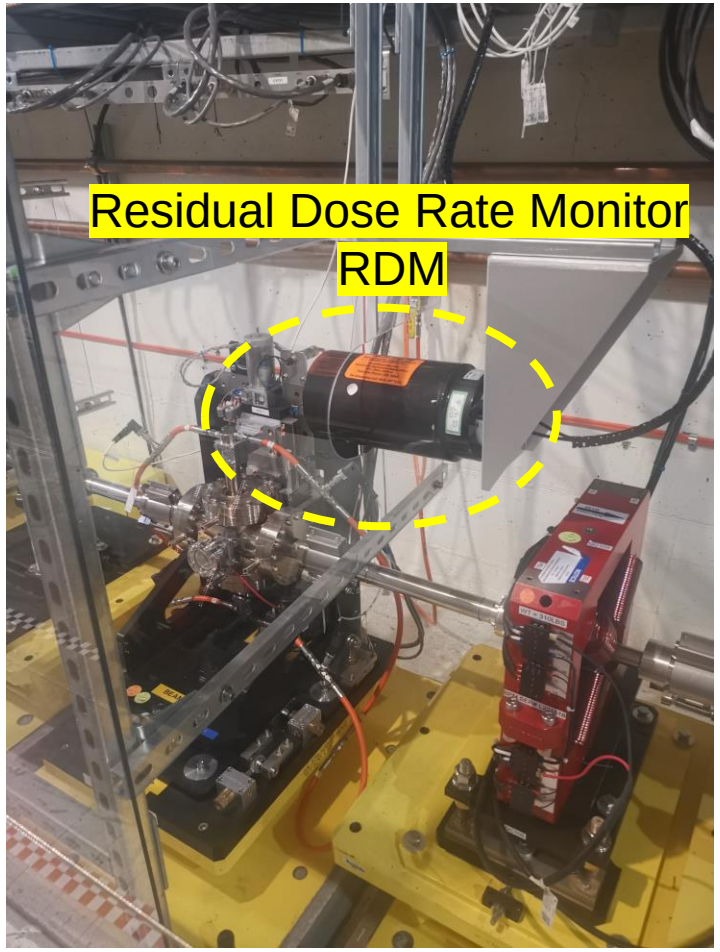
Response time of few nanoseconds → avoids saturation & keeps linearity

Slow decay after signal registered => not optimized for high repetition rates. Bigger, give more signal

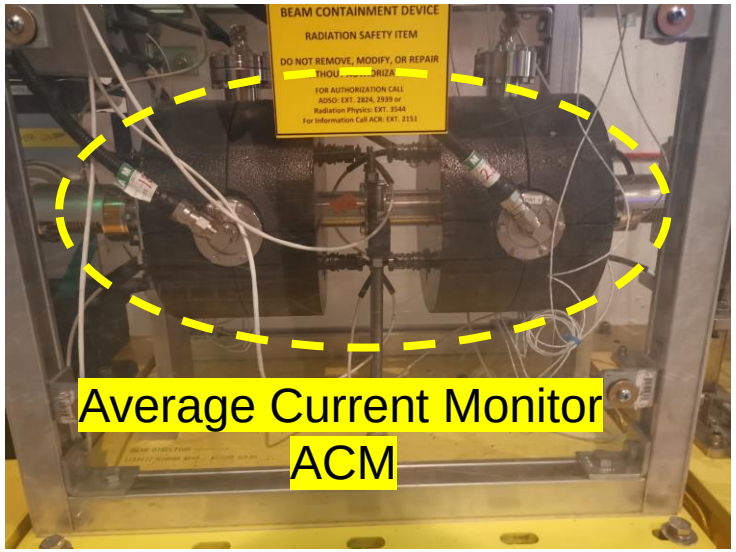

CIVIDEC diamond detector

Thermo Fisher FHT190 & Average Current Monitors

10 FHT190 and 2 ACMs

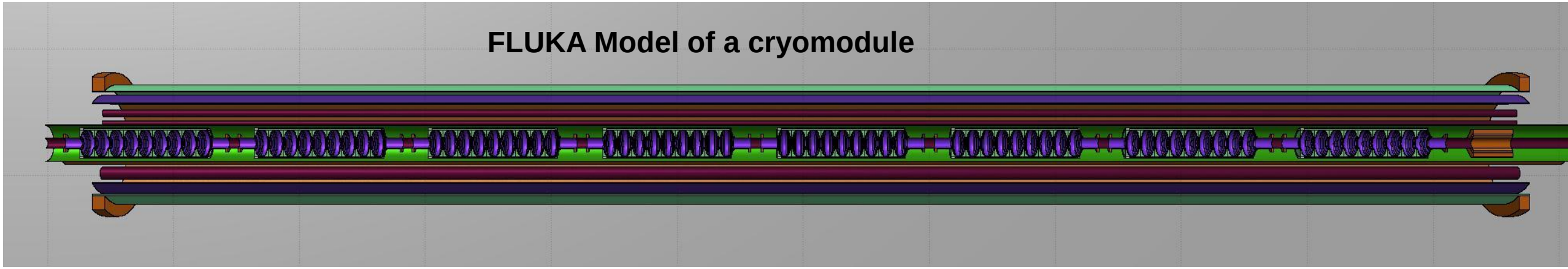


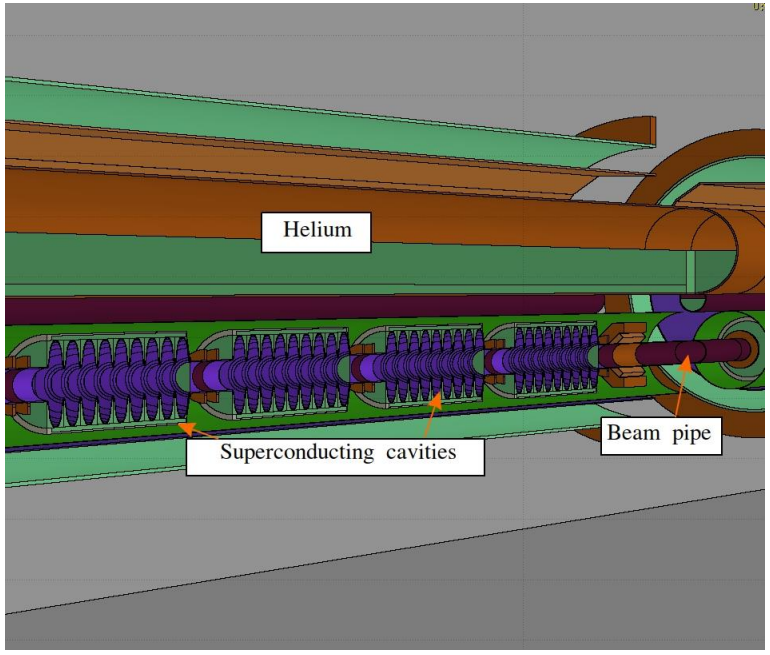
- FHT190 are ionization chambers
- Dynamic range: 1uSv/h to 5 Sv/h
- Energy range: 20 keV to 7 MeV
- Used for residual dose (self protected against activation)
- Very efficient so used also for monitoring

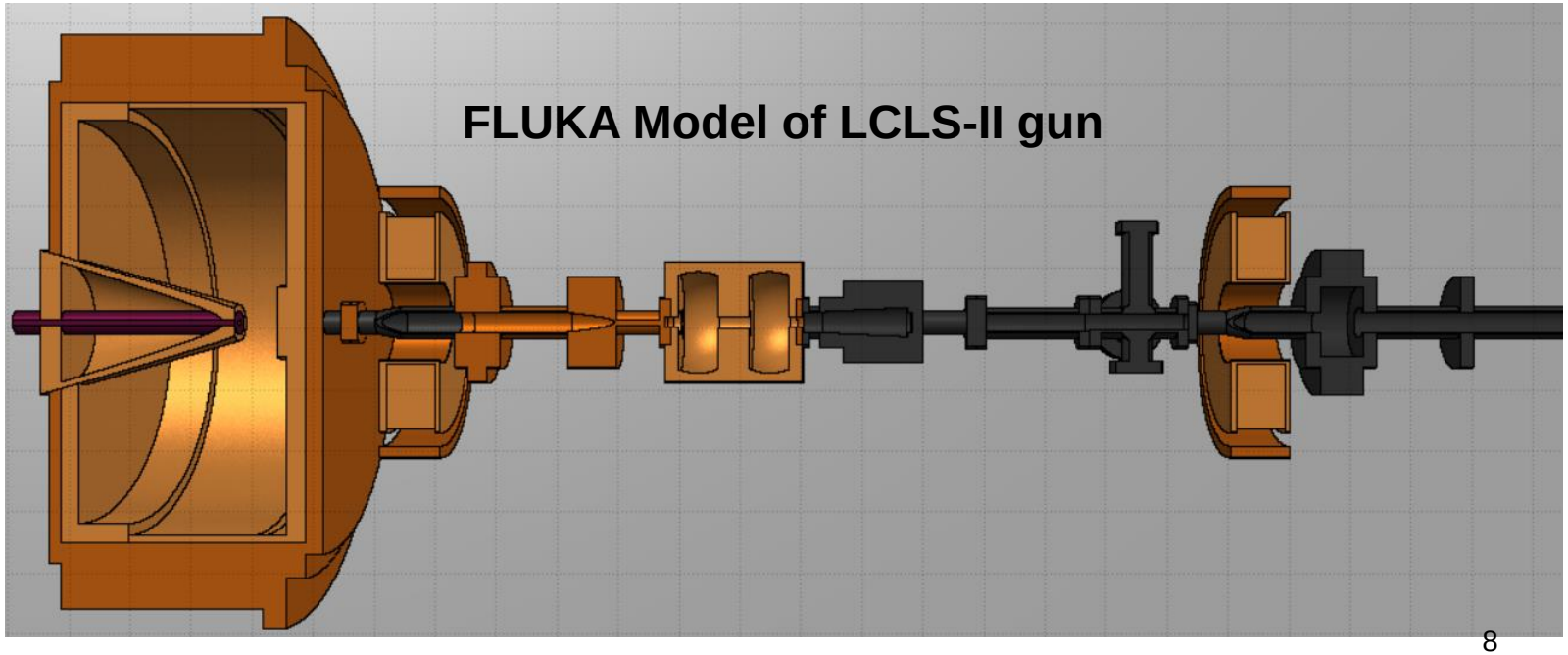


- Cavity in which beam induces RF signals that are processed
- Capable of measuring dark current
  - Frequency filter at 1.3 GHz (will include a bit of photocurrent due to its broad band signal

Field emission at SLAC and Monte-Carlo models







Field emission at SLAC and Monte-Carlo models

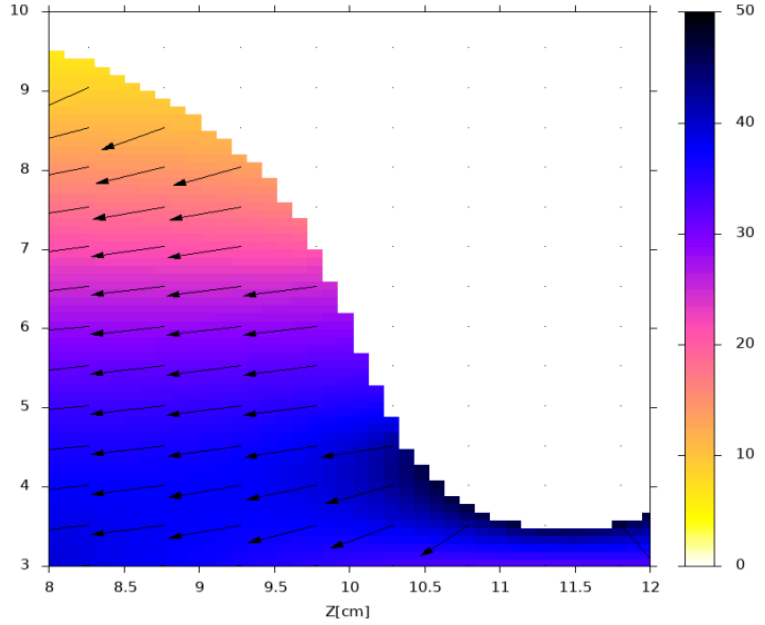
Emissions from Nb cavity walls due to high electric fields (via tunnel effect)

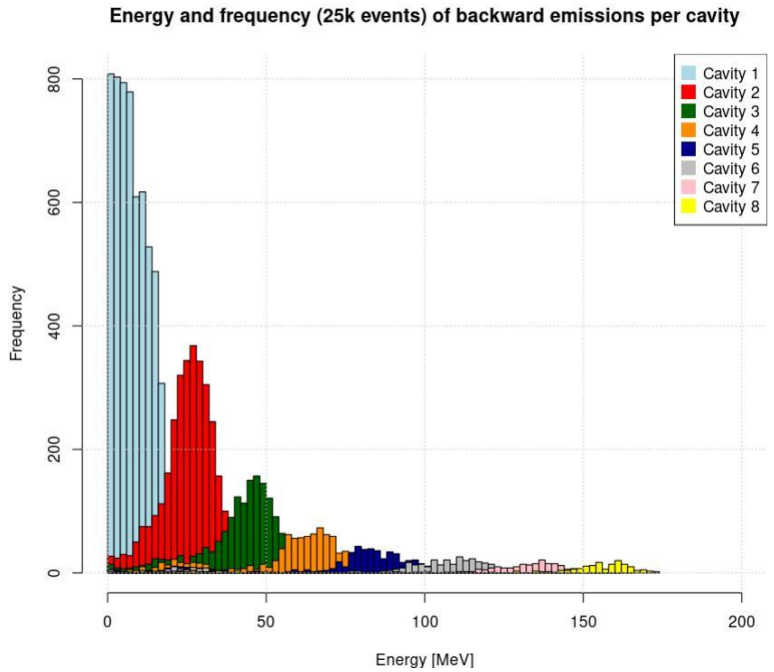
⇒ Induce “pollution” of the beam (not same repetition rate, not same energy, random directions)

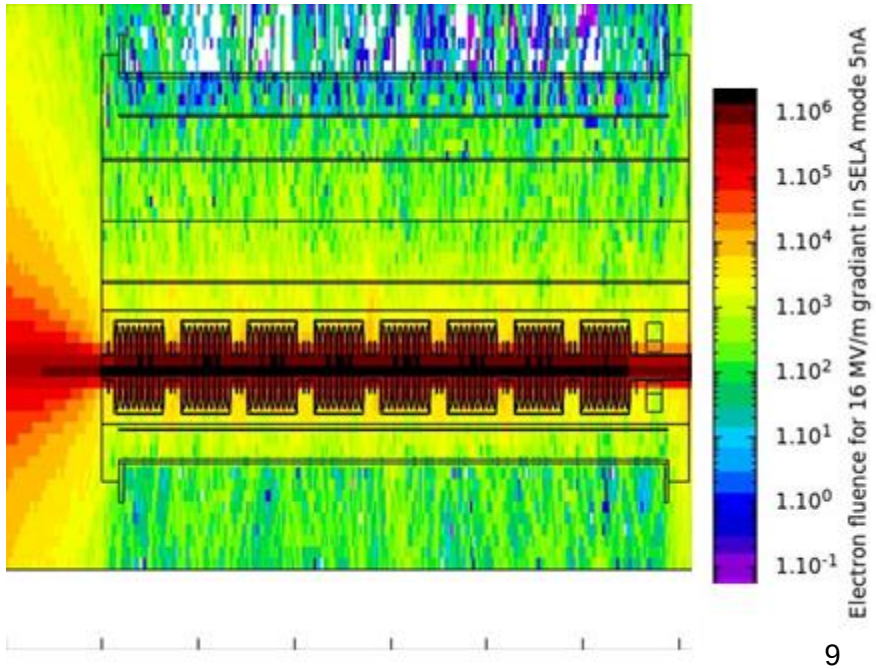
⇒ Produce cavity heating (performance degradation)

⇒ Can lead to high dose rates for which shielding might be required

⇒ Can also be simulated with FLUKA [`FLUKA: status and perspectives`, SATIF 15 proceedings]

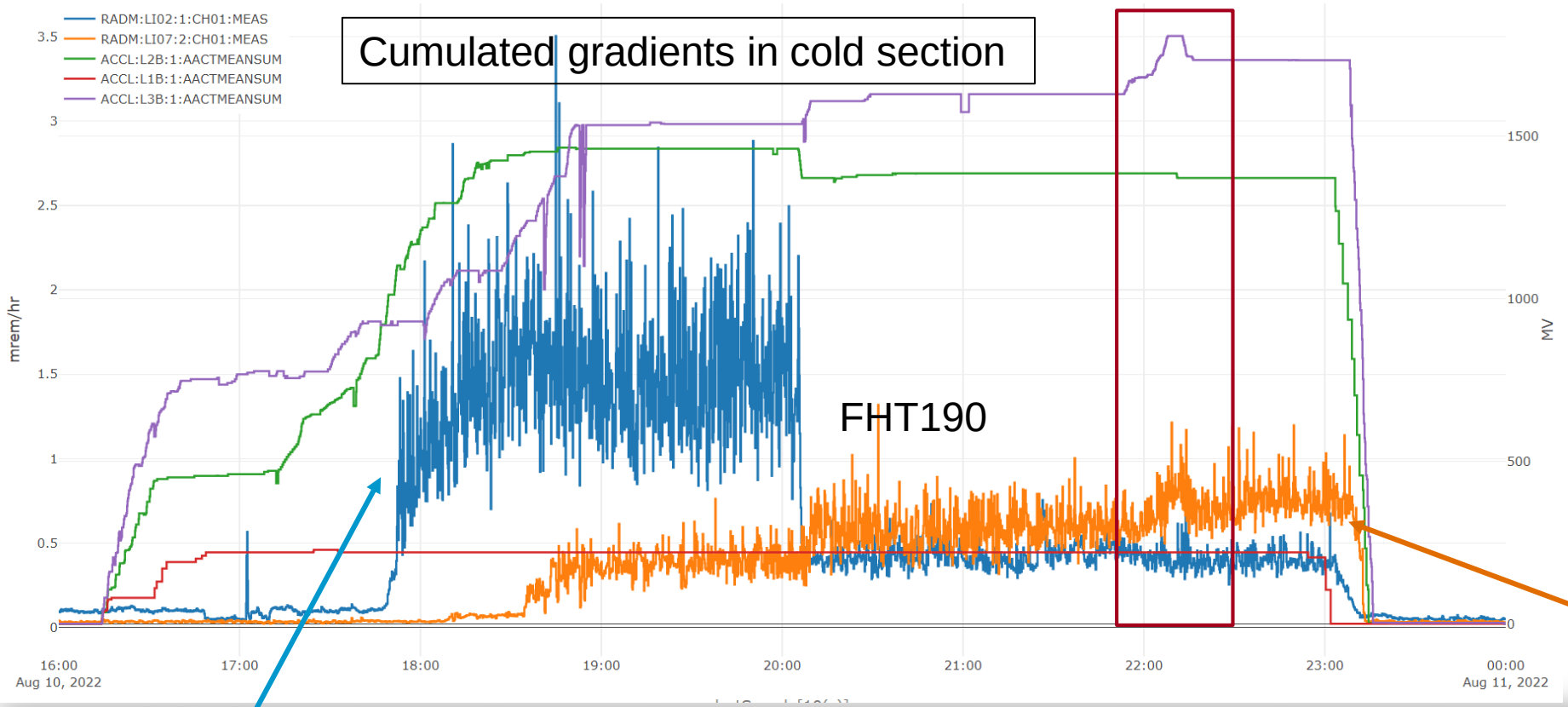






FHT190 example – Cryomodules ON / Beam OFF

100 mrem = 1 mSv



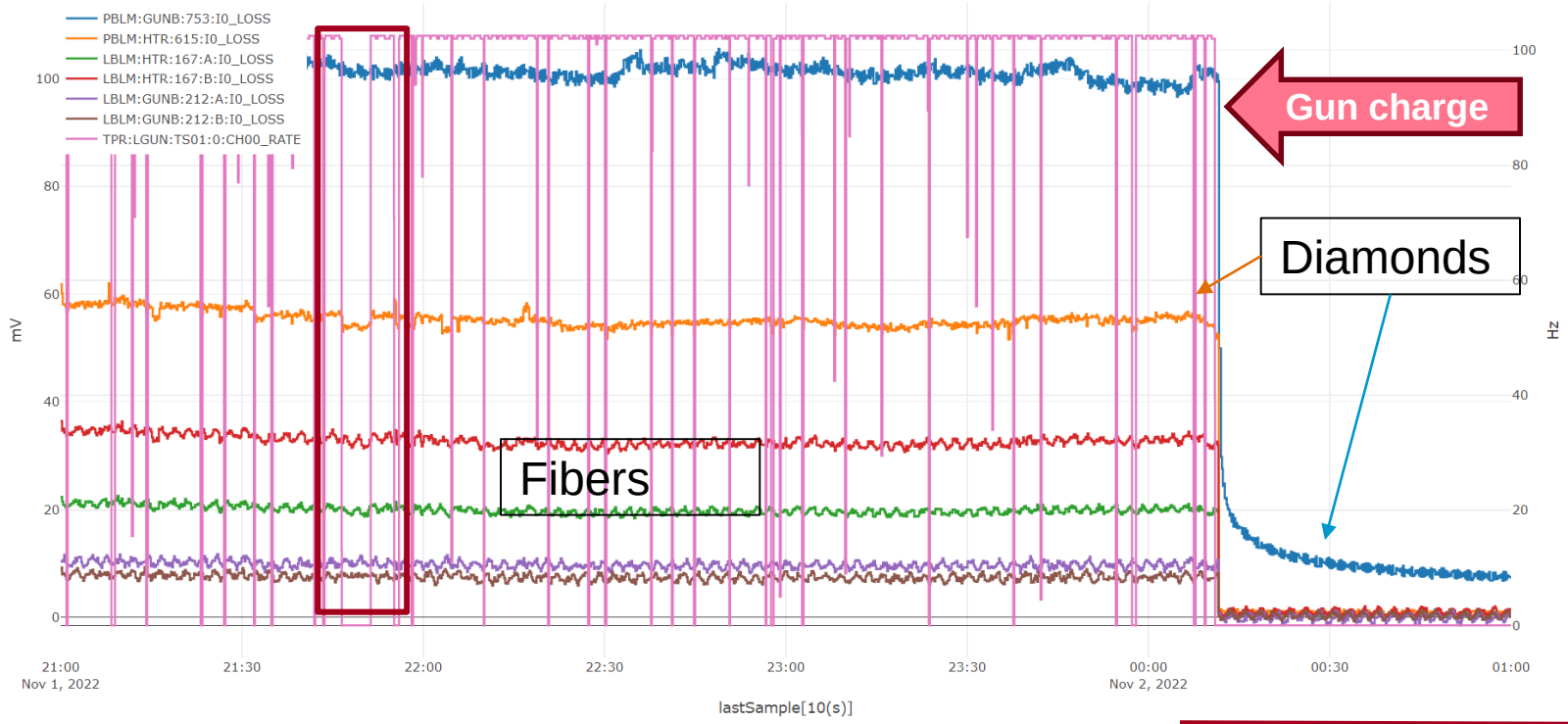
No beam, only RF turned ON

⇒ Signal recorded by FHT190 can only be field emissions

⇒ Correlated with the gradient increase

⇒ No signal from adjacent fibers in the tunnel except between L0B and L1B (see next slide)

Diamond and Cherenkov fibers – Beam ON / RF ON

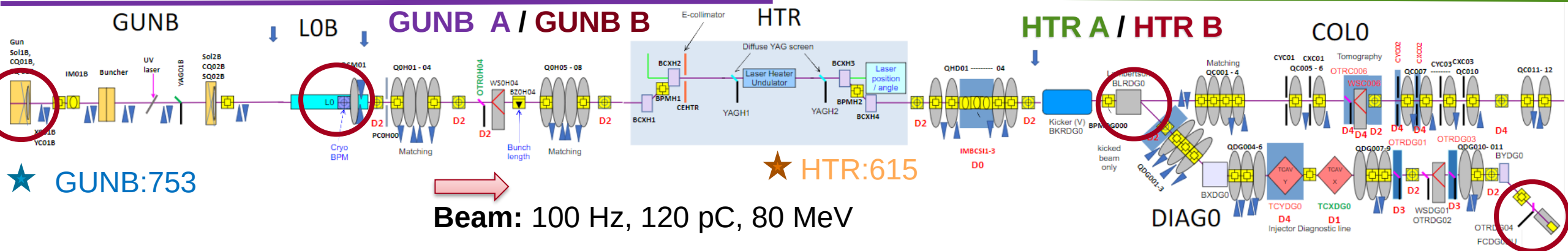


Beam interruptions (see pink curve)

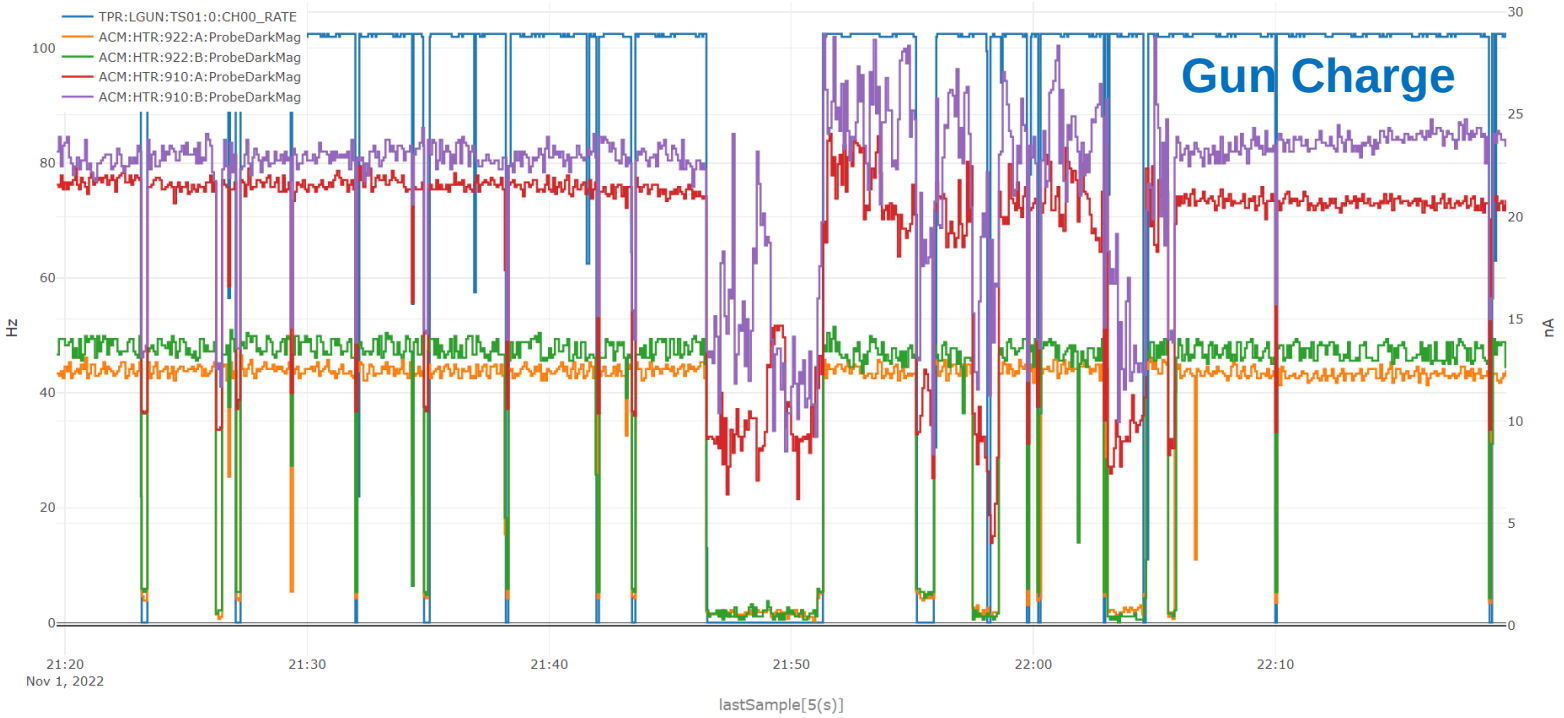
⇒ Even when beam is turned OFF, optical fibers are above background (detect field emissions from the gun)

⇒ More important in HTR than in GUN area due to a collimator right after the cryomodule

⇒ Clearly see the decay of the blue diamond det. (polycrystalline type)



Average Current Monitors – Beam ON / RF ON

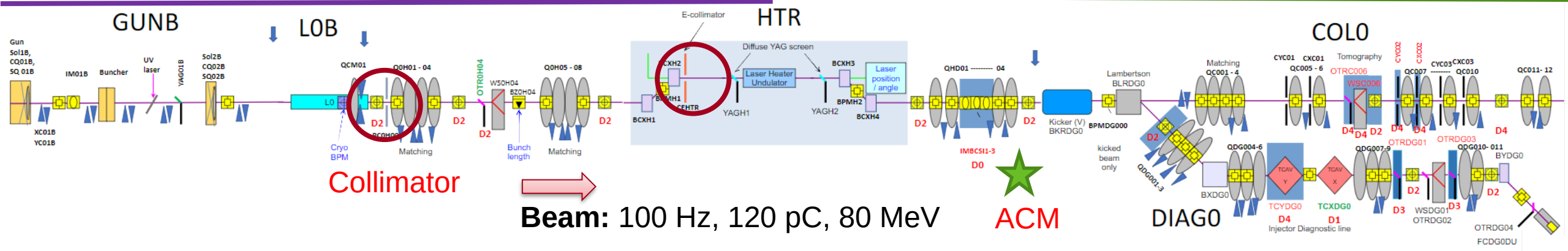


Focus on a longer beam interruptions

⇒ Probe on ACMs to measure dark current

⇒ Dark current very low (between 1 and 10 nA) because removed by collimator after CM

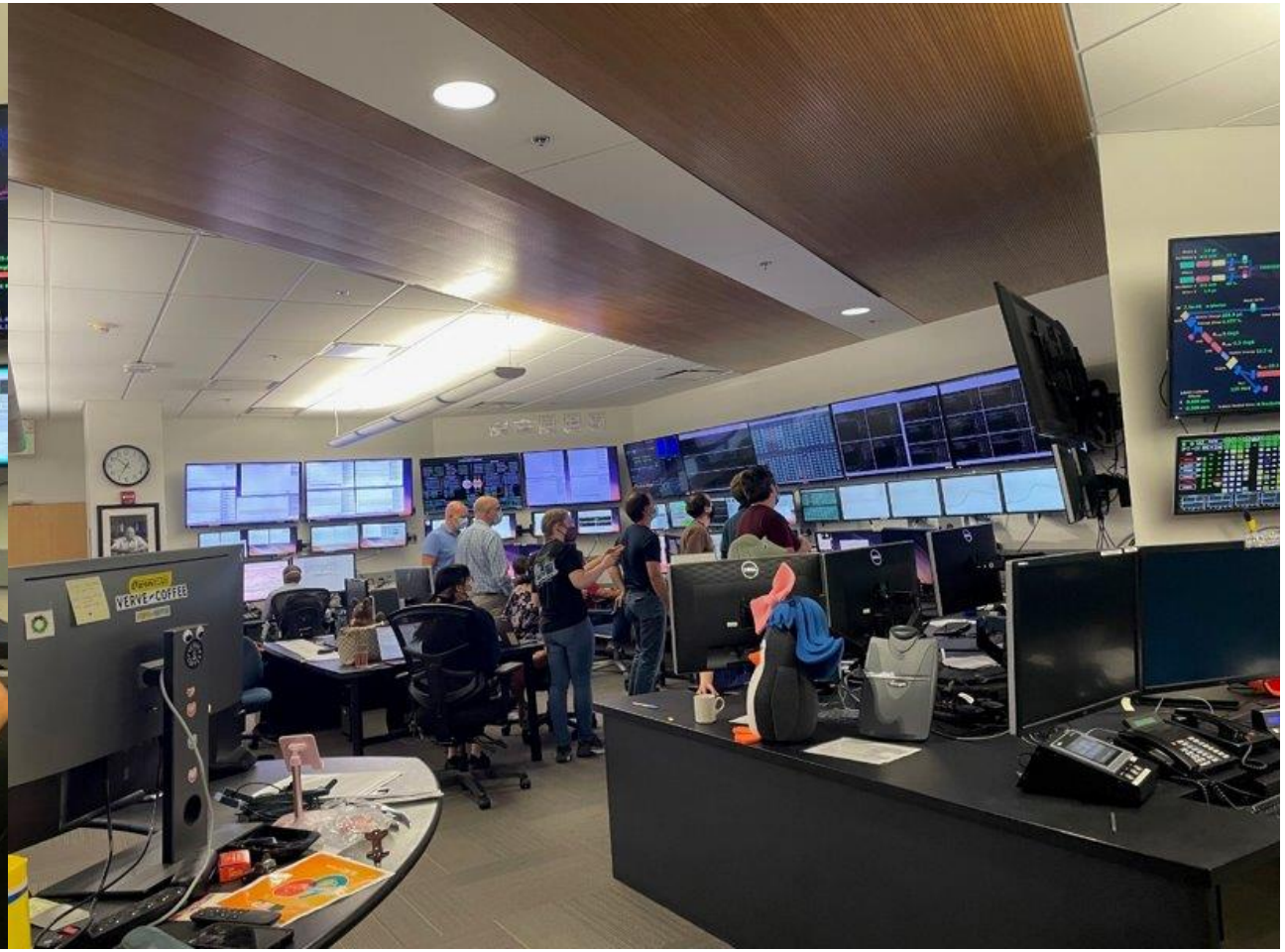
⇒ Fiber exp ~ 7 mV/W. HTR fiber read 35 mV so ~5W of dark current but collimator is thick target (we can consider factor 10-20 higher)



Conclusions

- Field emissions
  - can be responsible of high doses and produce degradation of the beam parameters and beam components
  - are difficult to distinguish from beam (ACMs help)
  - are high frequency pulsed field (considered continuous at 1.3 GHz for CM / 186 MHz for gun)
- Fibers and diamond detectors seem to particularly detect gun field emissions but not CMs at 16 MV/m gradient. Thermo Fisher FHT190 detect all field emissions but difficulty to locate the source
- Diamonds detector can be used for short frequency pulsed radiations using the single crystal type. It would fail with polycrystalline types due to the decay time
- We want to reproduce the experiments with numerical simulations using the models developed (for validation as well as better explanation of the phenomenoms)

QUESTIONS ?



Next commissioning phase in two days, Thursday December 8th