IOTA diagnostics and experiments with synchrotron-light photomultipliers

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Main goals

Exploit the sensitivity and fast time response of photomultipliers for

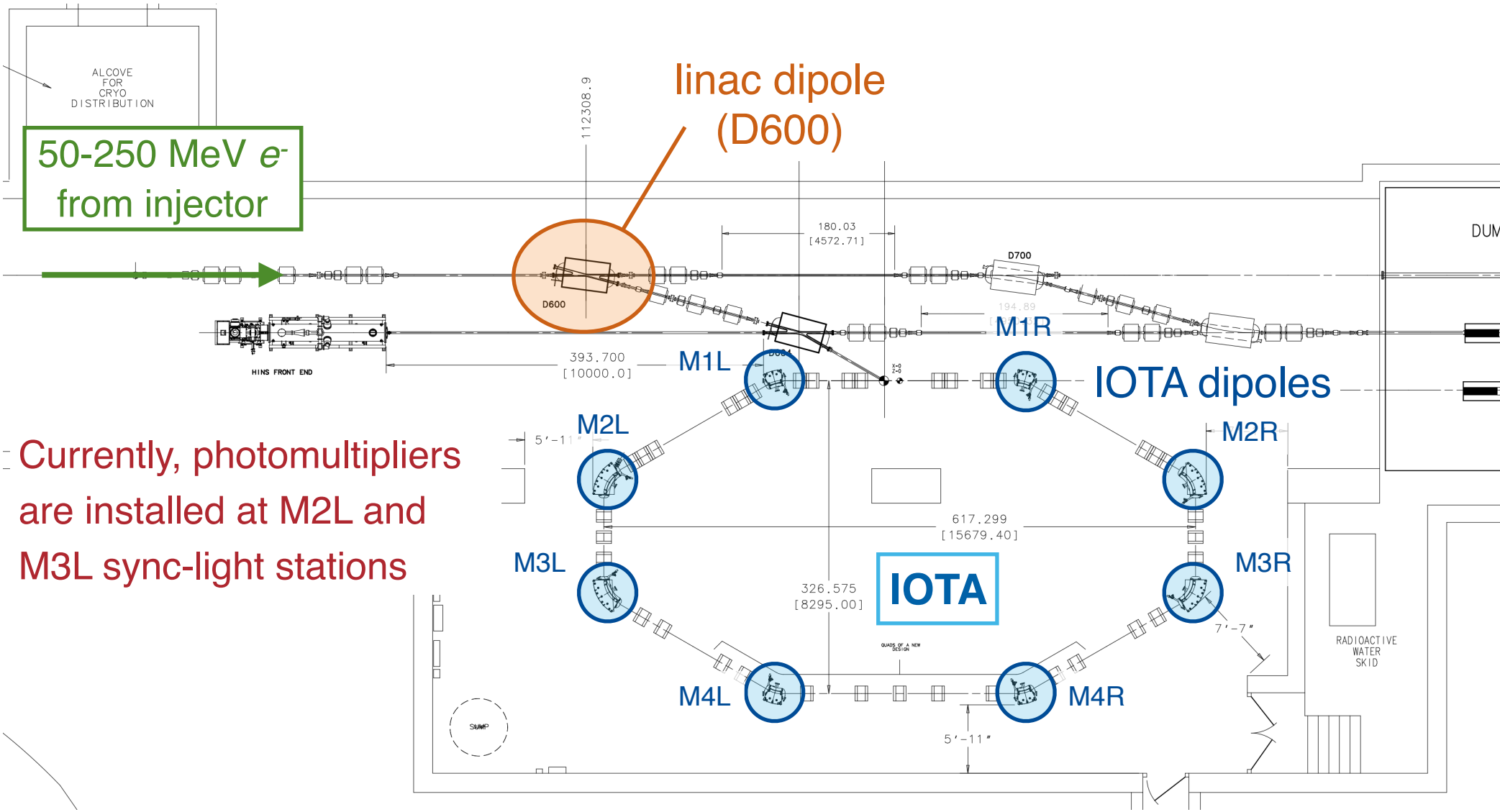
Beam diagnostics

- intensity measurement with wide dynamic range, from 10^9 down to single electrons
- lifetime measurements vs. beam intensity
- turn-by-turn beam positions and arrival times: synchrotron oscillations, beam jitter, etc.

Physics experiments

- time distribution of individual electron losses
- time structure of synchrotron radiation from single electrons
- properties of undulator radiation
- …

Experimental layout



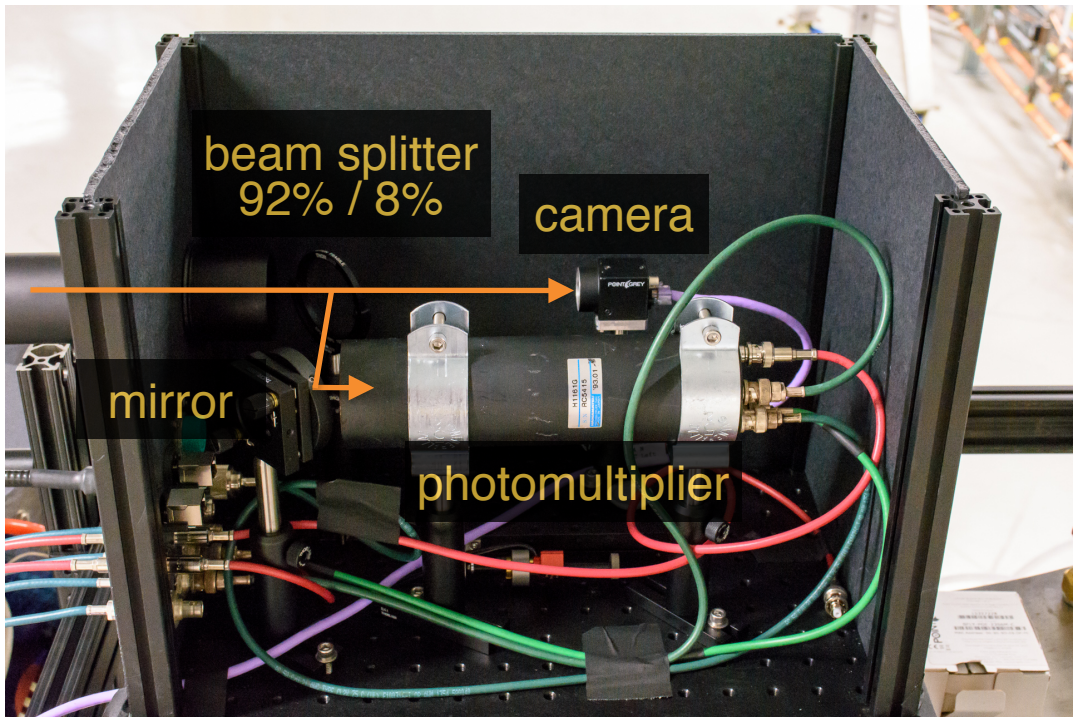
Currently, photomultipliers are installed at M2L and M3L sync-light stations

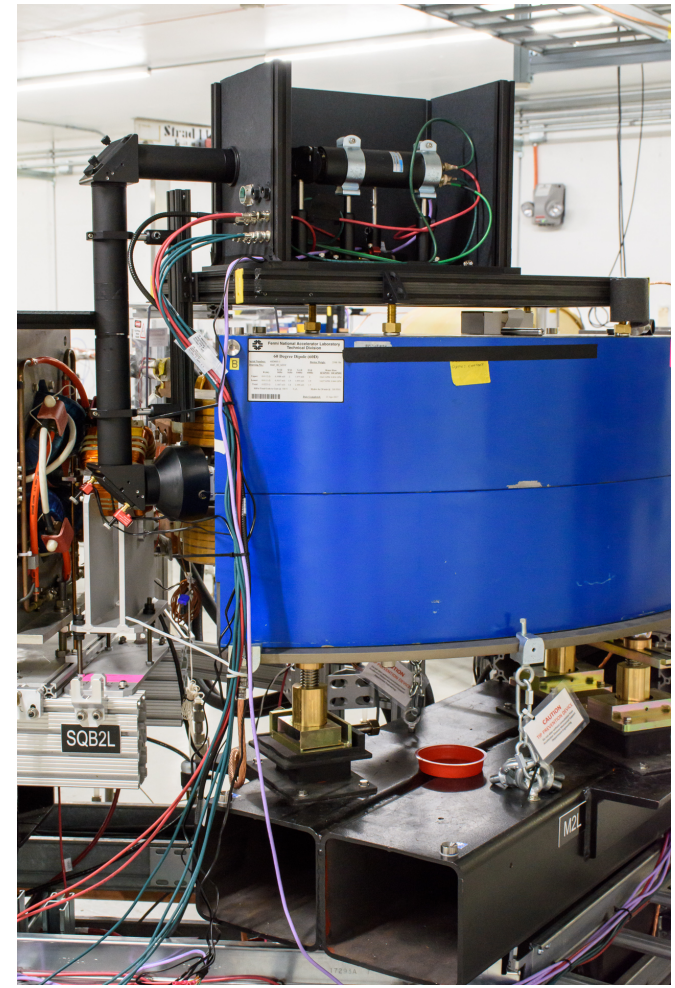
M2L sync-light station

Equipped with beam splitter, camera, PMT

Dedicated to continuous intensity monitoring for operations

Provides intensity device N:IBEASL





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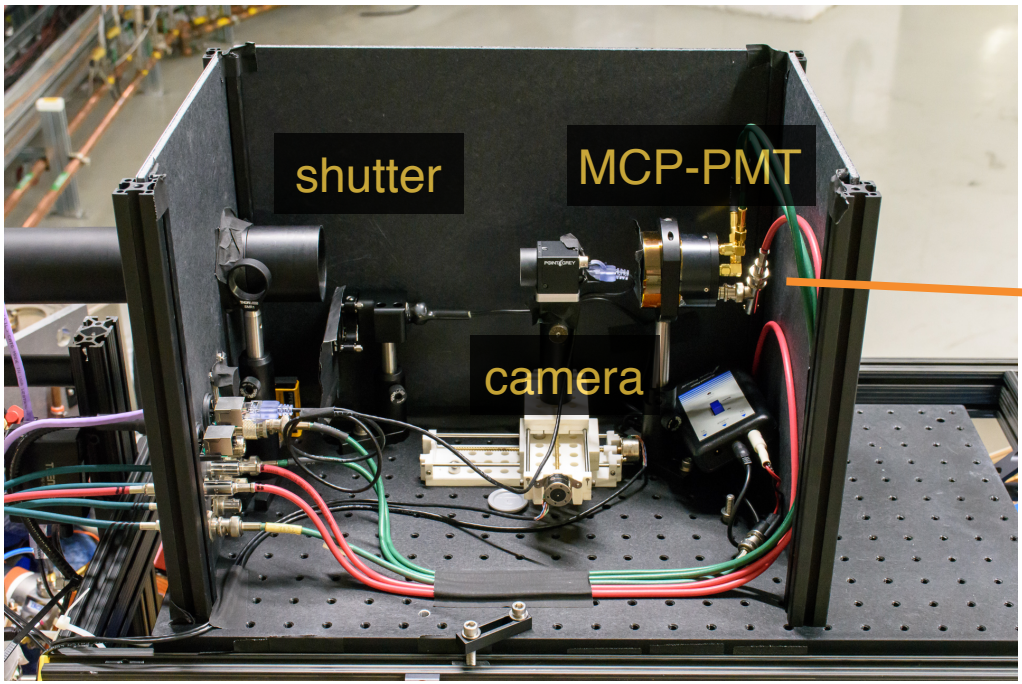
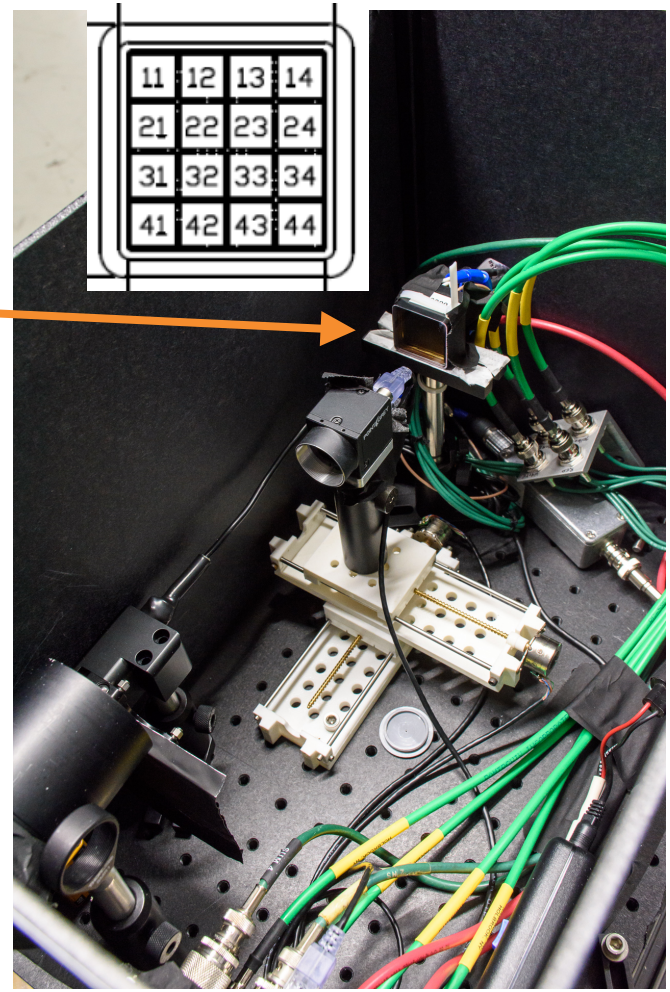
M3L sync-light station

Equipped with micro-channel plate photomultiplier for timing measurements

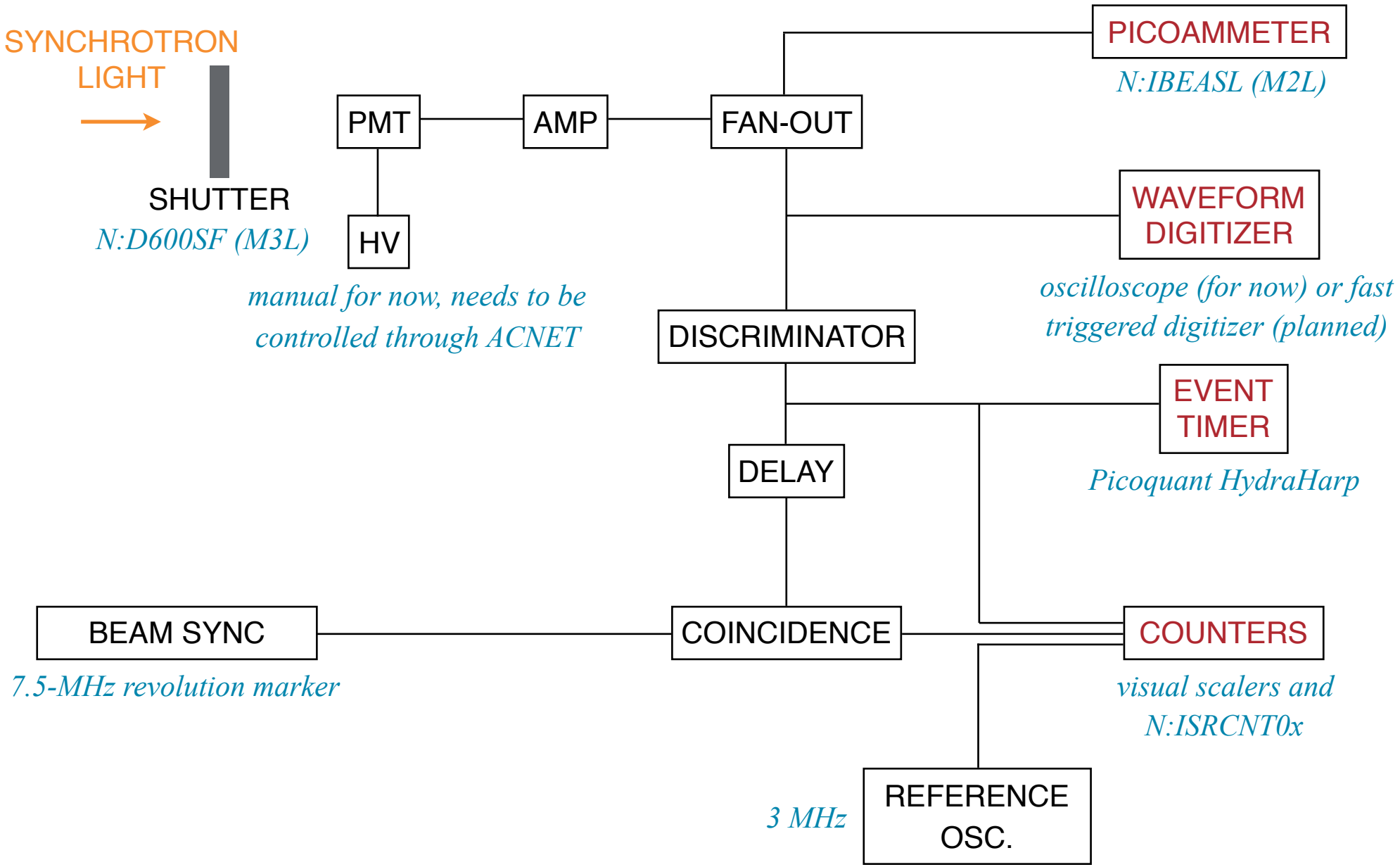
Camera can be shifted out to expose the photodetector





On Wed Feb 6, replaced Hamamatsu gated MCP-PMT with multi-anode Photonis MCP-PMT: larger area; segmented for transverse position measurements (4x4 matrix now wired as 2x2); no gating cross-talk on signal

Signal processing and data acquisition (mostly ESB RR 903-904)



Recent IOTA studies

Tue Jan 29 (parasitic)

- acquisition setup, signal timing
- recorded turn-by-turn beam arrival times for 10 s with 0.4 mA in the machine

Thu Jan 31 (6 h)

- recorded current signal and count rate of M2L PMT with varying gain, from injection down to single electron
- measured sensitivity of M3L MCP-PMT (Hamamatsu) — not as good as PMT or cameras due to intrinsic current limit and gate cross-talk
- collected arrival time data of single circulating electrons for offline analysis

Thu Feb 7 (6 h)

- verified signals from M3L multi-anode MCP-PMT (Photonis) — 4 anode signals can be used for transverse positions and arrival times
- compared single-electron MCP-PMT sensitivity with PMT and cameras
- recorded M2R camera intensity data for offline analysis of single-electron loss times

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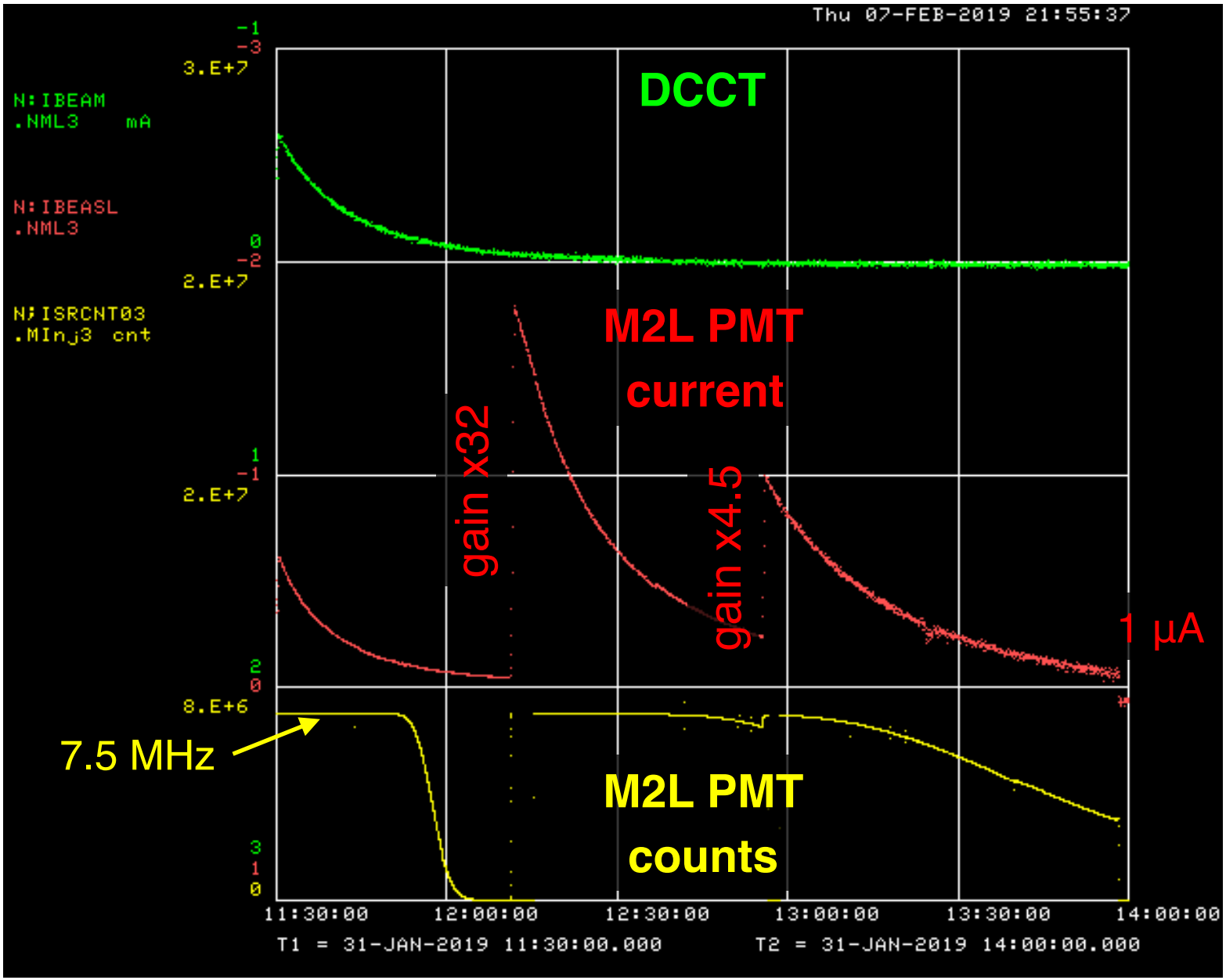
Operational considerations

Dark current from linac affects current readout of M2L PMT. Need to close the laser shutter and insert Faraday cup for sensitive measurements (or shield M2L station).

Single-electron sensitivity requires a conventional PMT that sees most of the synchrotron radiation. Consider replacing the 92%/8% beam splitter at M2L (or adding a PMT to another station with a different beam splitter).

Example of intensity and lifetime measurement



Current measurement can easily go down to microamps

Lifetime improves with decreasing intensity

Single-electron sensitivities rely on counting rates