Trigger System for a Thin Time-of-flight PET scanner

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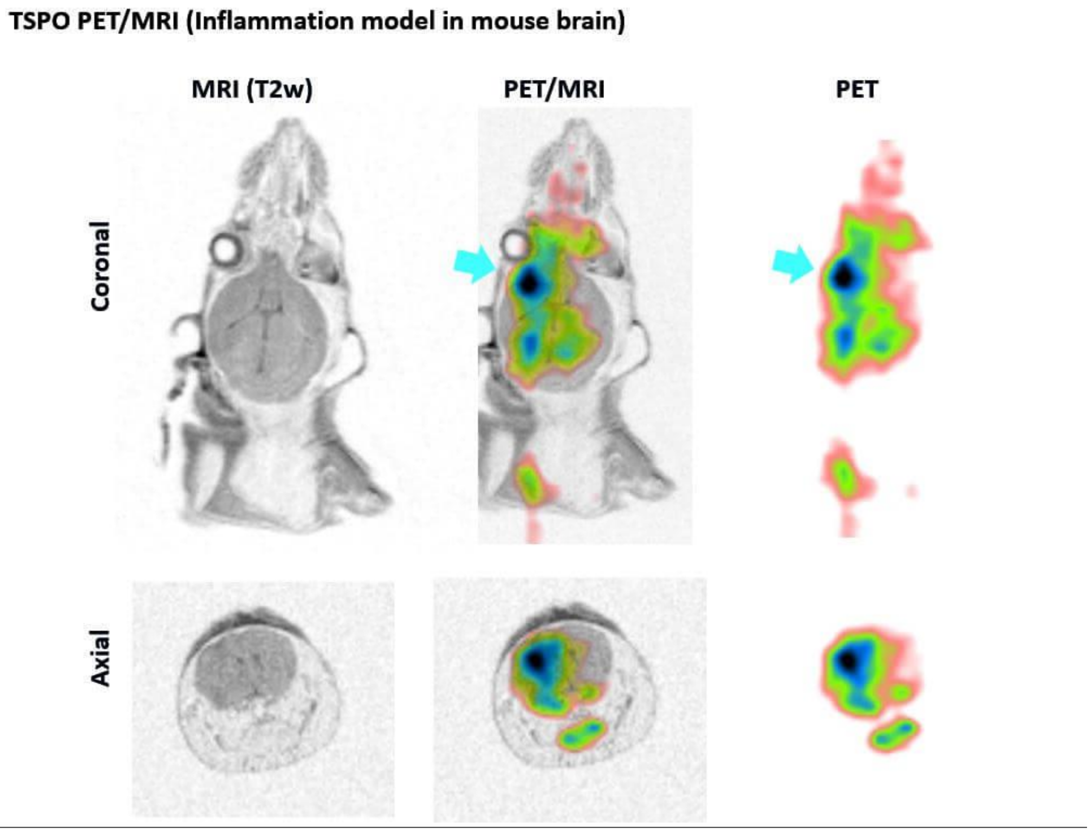
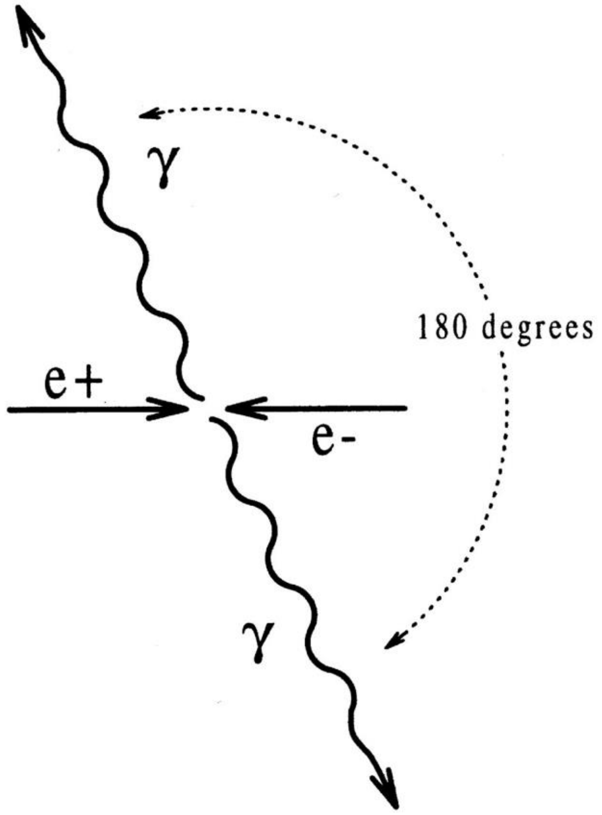
The TT-PET Project

- Design of a Thin Time-of-flight PET (TT-PET) Scanner
  - Based on Silicon Pixel Technology
  - Insertable in an existing MRI machine
  - High Magnetic field compatibility
- Metabolical Picture from PET machine
- Structural body picture from MRI



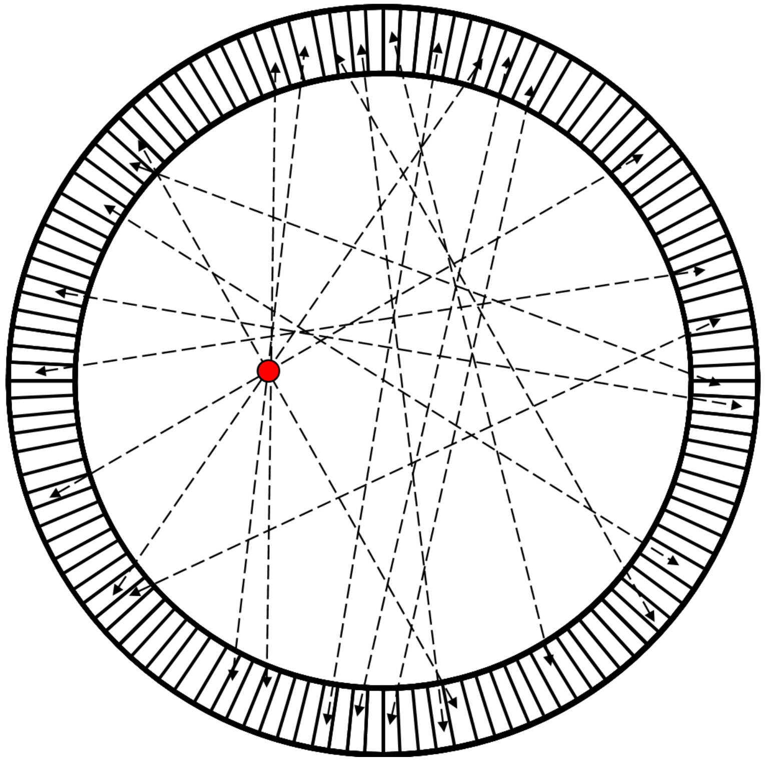
Working Principle of PET Scanners

- Trace Tissue with radioactive Element
  - Inject radioactive isotope into patient
  - Concentration in Tissue with high metabolism
- Isotope decays in patient
  - β^+-Decay emitting a positron
  - Emission of 2 back-to-back photons
- “Line of response” associated to decay
  - Cross points are candidates

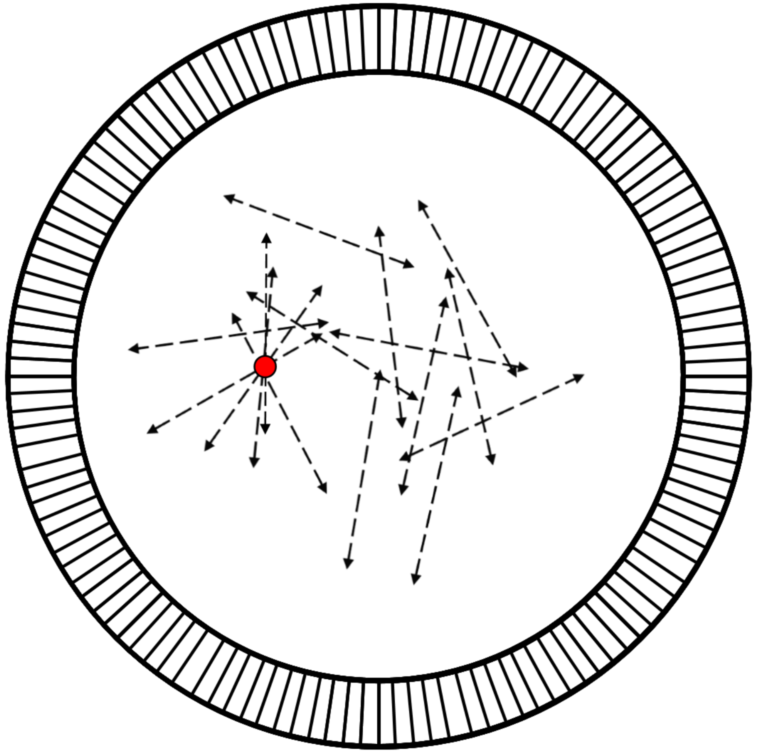


Better Tracing with TOF

Conventional PET



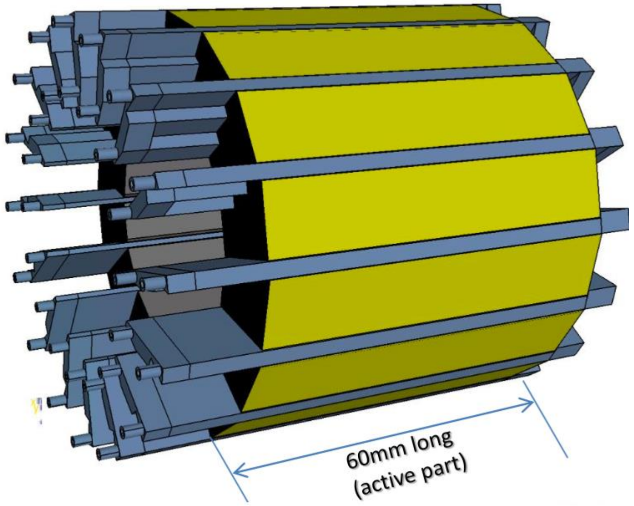
TOF PET

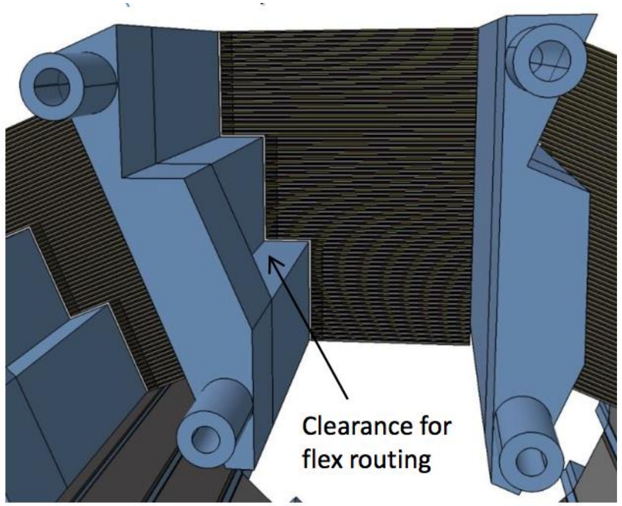


alternately
alternately

TT-PET Scanner Structure

- Small animal Scanner
  - 4 cm inner diameter and 1.4 cm thickness
  - Geometry restricted by MRI coil
- Cylindrical Design with 16 “Towers”
  - 60 Detection Layers in a Tower
  - Precise depth-of-interaction measurements
  - Detection and Cooling blocks alternably





Detector Layer Structure

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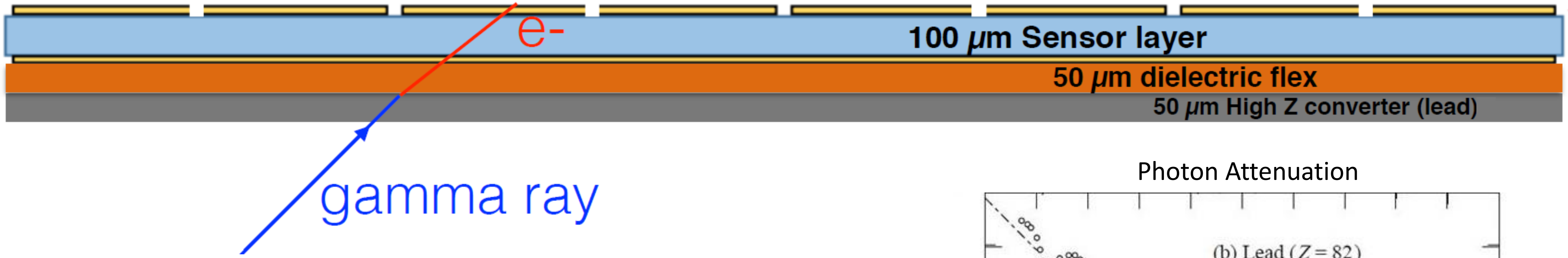
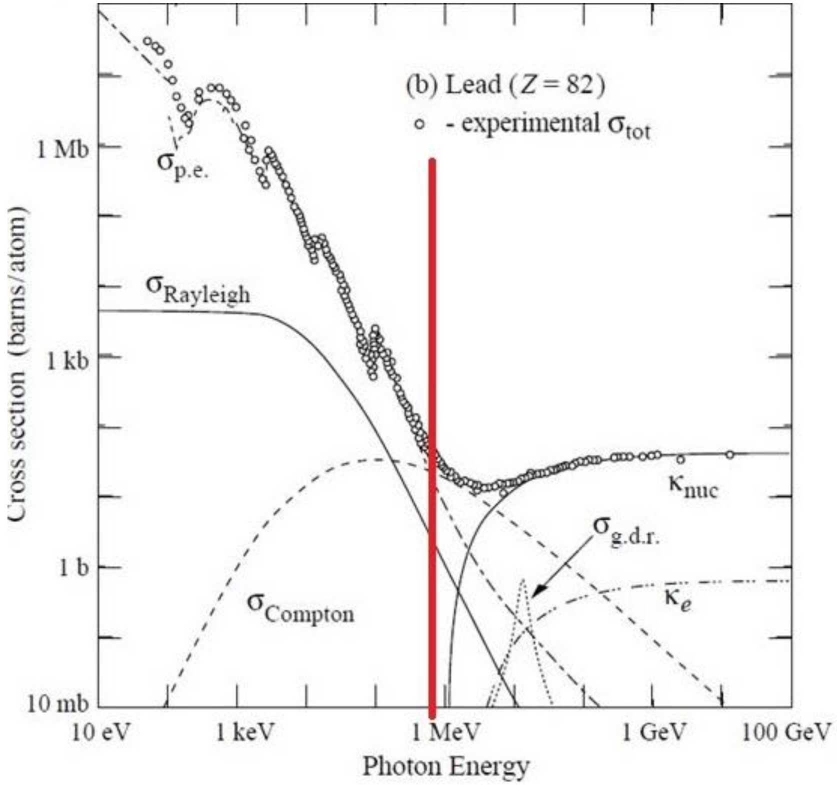


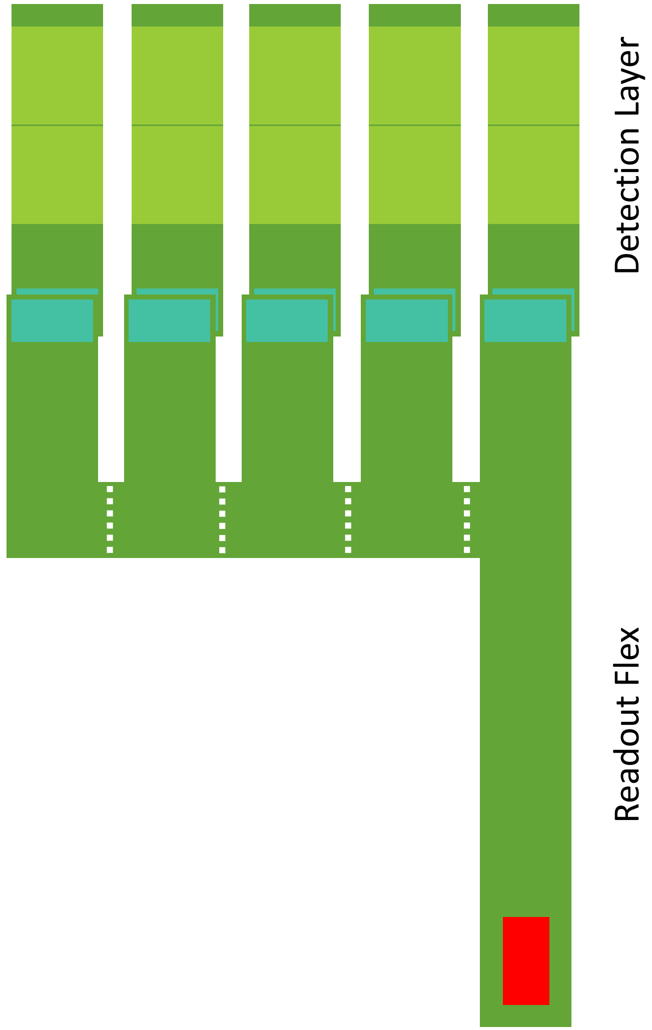
Photon Attenuation



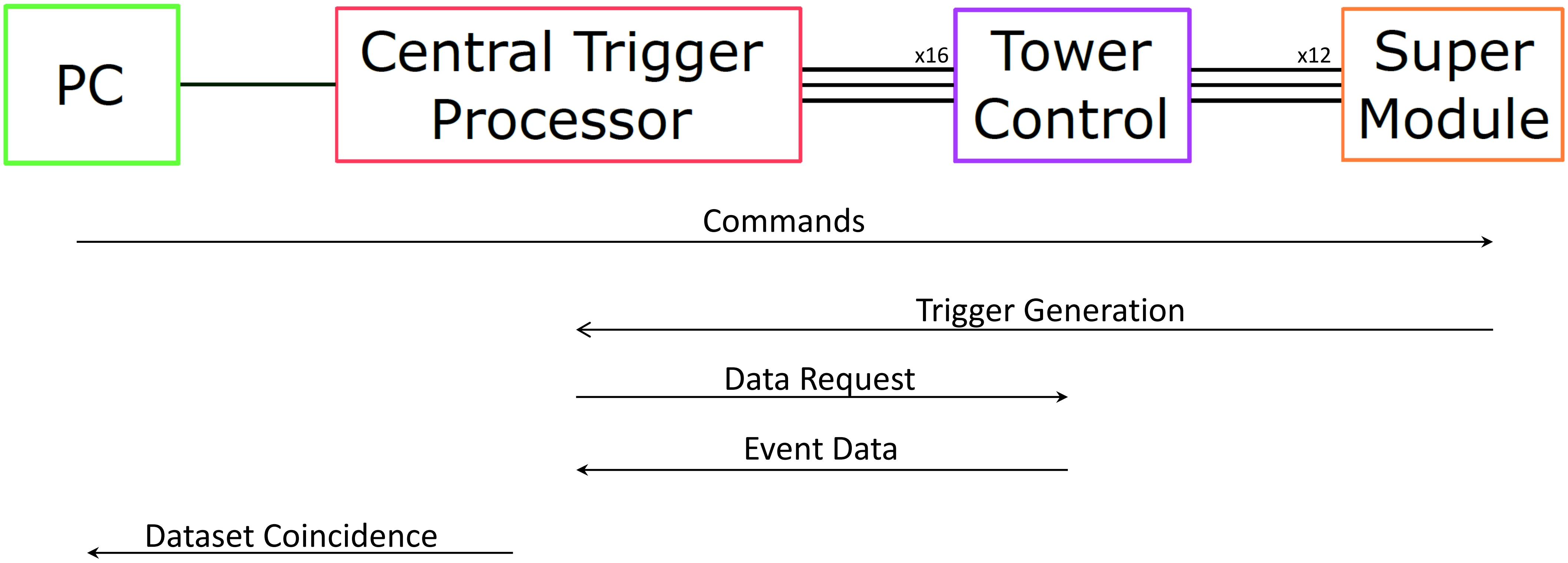
- Photon conversion via Compton Scattering and photoelectric Effect
  - efficiency 0.5% per Layer (25% for a Tower)
- Very fast Silicon Sensors
  - Timing Resolution $\sigma_t \approx 100\ ps$ (goal 30 ps)
  - 5 Layers daisy-chained to “Super Module”

Super Module (SM)

- Formed by 5 daisy chained Detector Layers
- Layers in SM share Data, CMD and CLK line
  - Data Bus with priority to closest Detection Layer
- Event Readout generally not in Order
- Asynchronous hit Line do indicate an Event
  - Used to generate Trigger
- Readout Flex folded to stack Layers



Full Readout Chain



Event Rate and Data Pressure

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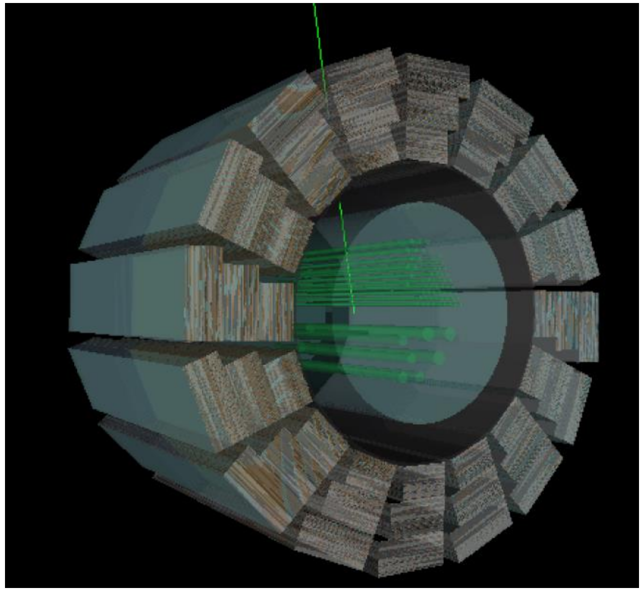
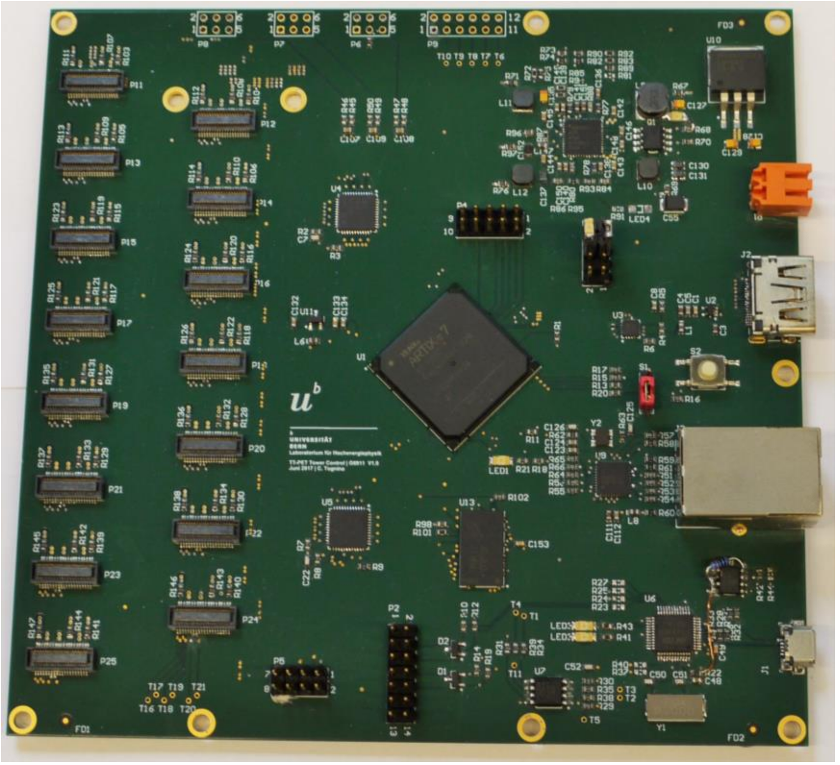
- Readout designed for 50 MBq source
  - 19.2 MHz single Hit rate
  - 5 MHz possible Coincidences
  - 1.2 MHz real Coincidences
- Hit rate per Tower, 1.2 MHz
  - 630 kHz after Trigger Selection
  - Data Rate of 61.2 Mbit/s



Tower Control (TC)

- Intermediate board controlling one single Tower
- Provides HV, LV and CLK to the Chips
  - 36 LV lines, 12 HV lines
- Converts asynchronous to synchronous Trigger
  - Generates Time of Arrival Trigger with 6.7ns window
  - No information where Hit occurred
  - Passes Trigger to CTP
- Readout and temporary Storage of Data
- Custom Board designed in Bern



Central Trigger Processor (CTP) Board

- Main board, controls the whole DAQ system
  - Ethernet connection to PC
  - Commercial Board Xilinx ZC706
  - Connection to the 12 TC Boards
  - Provides CLK to TC boards
- Two Stages of Data Suppression
  - Compare Timing Difference of Trigger and Data
  - Data Request only if multiple Trigger within 6.7ns
- Comparison of exact timing of Events
  - If $\Delta t < 500$ ps considered as Coincidence and sent to PC
  - Max. flight time ≈ 130 ps

Progress and Conclusions

- Completed Firmware for CTP and TC
  - CTP + TP Firmware merged and tested
- Communication PC to CTP
  - Computer Software
  - Ethernet Communication set up
- Next steps:
  - Implementation of Calibration
  - Test the readout chain with Chip

BACKUP

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Data Pressure Readout

- Data Rate, TCs to TC
  - 1 Gbit/s (61 Mbit/s per Tower)
  - 1.5 Gbit/s with 8b10b encoding
- Data Rate, CTP to PC
  - 1.7 Gbit/s
  - Capacitance Ethernet 1 Gbit/s
  - Capacitance PCIe > 10 Gbit/s