**Introduction**

- **bias tuning**
- **Configurable matching window**
- **Compact design**
- **Mu3e fiber detectors**
- **Linearized Time**
- **SPI**
- **FWHM**
- **LVDS serial link**
  - Test chip fabricated in 2015
  - Bridge
  - Picosecond pulse laser with wavelength of 460 nm
  - **System**
    - **50 ps**
    - **Timing threshold and energy threshold triggering**
  - **Single Photon Timing Resolution**:
    - **Silicon proven in STiCv3**
    - **Low timing jitter**
    - **SiPM**
    - **Mu3e Tile detector: 100 H. Chen**
    - **UMC 180 nm**
    - **Max. matching window width: 2.5**
  - **External validation in L1_FIFO**
  - **LVDS driver**
  - **Fully**
  - **Munwes**
  - **Focused Laser spot on single pixel: < 3 µm**
  - **Jitter < 20 ps**
  - **block diagram**
    - **time binning**
    - **Common**
      - **Termination**
    - **Mu3e Fiber detector: 500**
    - **Matching window resolution: 78 ns**
    - **Single**
      - **Temperature dependent**
    - **Silicon**
    - **SiPM**
    - **32**
    - **SiPM**
    - **Designed for 1.28**
    - **readout chip with high timing**
    - **CRC for**
    - **High Dark Count Rate (DCR)**
    - **differential structure**
    - **HV**

**Motivation**

- **Mu3e experiment**
  - Looking for new physics by searching for 
    \( \mu^+ \rightarrow e^+e^\nu \), which is forbidden in standard model (BR < 10^{-16}).
- **Challenges on readout electronics:**
  - **High timing resolution** to reduce the combinatorial background and to facilitate event reconstruction:
    - **Mu3e Tile detector: 100 ps**
    - **Mu3e Fiber detector: 500 ps**
  - **High event rate** to collect enough data in reasonable experiment run time:
    - **Mu3e Fiber detector: 1.3 MHz/channel**

**Silicon Photomultiplier**

- **Array of Avalanche Photodiodes in Geiger mode allows for photon counting measurements.**
  - **Pros:**
    - Low timing jitter
    - High Gain (~ 10^6)
    - Low operating voltage (20 ~ 100 V)
    - Compact design
    - Insensitive to external magnetic field
  - **Cons:**
    - Temperature dependent
    - High Dark Count Rate (DCR)

**MuTRiG Introduction**

- **32-channel Mixed-Mode ASIC**
- **UMC 180 nm CMOS technology**
- **SiPM readout chip with high timing resolution and high data rate**
- **System On Chip**:
  - analog frontend + TDC channel
  - digital part
- **External validation in L1_FIFO**
  - **High speed LVDS data link (1.28 Gbps)**
  - **Configurable output event data structure**
  - **CRC for data transmission error detection**
  - **Event counter for event rate monitoring**
  - **SPI slow control for chip configuration**
  - **Prototype submitted in Sep. 2016**

**Analog Frontend and TDC**

- **Analog frontend:**
  - Fully differential structure
  - Single-ended or differential connection scheme with SiPM
  - Timing threshold and energy threshold triggering
  - Linearized Time-over-threshold method for energy measurement
  - SiPM bias tuning within ~500 mV
  - Jitter < 20 ps for input charge > 300 fC
  - Silicon proven in STiCv3[1] submissions
- **TDC[2]:**
  - 16-stage VCO ring locked by PLL to 640 MHz external clock
  - 50 ps time binning
  - Jitter < 40 ps
  - < 0.1 LSB with DNL correction
  - Silicon proven[1]
- **Single Photon Timing Resolution Measurements with STiCv3:**
  - **SiPM: HAMAMATSU MPPC S13360-1350CS**
  - Picosecond pulse laser with wavelength of 460 nm
  - Focused Laser spot on single pixel: < 3 µm
  - Single Photon Timing Resolution: ~150 ps FWHM

**External Validation in L1_FIFO**

- **Reduced load of output data link** by only sending event data within matching window of the trigger signal:
  - Configurable matching window
  - Matching window resolution: 78 ns
  - Max. matching window offset: 1.25 µs
  - Max. matching window width: 2.5 µs

**Gigabit LVDS Serial Data Link**

- **Boosted output data rate** with gigabit LVDS transmitter and double data rate serializer:
  - Bridge-Switched Current Source LVDS driver
  - Common-mode feedback
  - Double data rate
  - Designed for 1.28 Gbps
  - LVDS serial link test chip fabricated in 2015
  - Eye diagram of PRBS data with 8b/10b encoding

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**Reference:**