



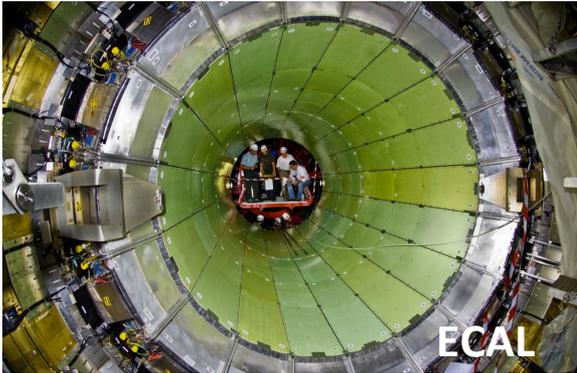
ToF chip for PPS timing

Joao Varela
LIP Lisbon

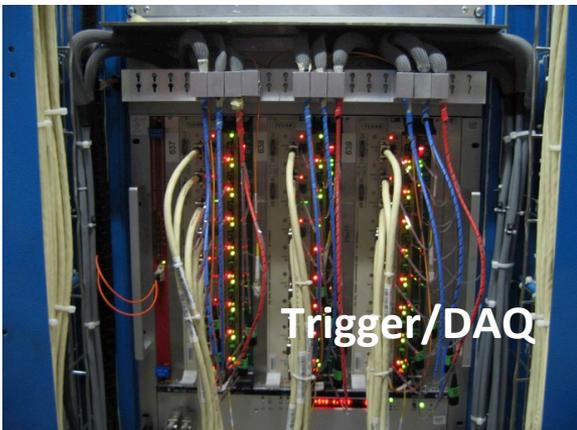
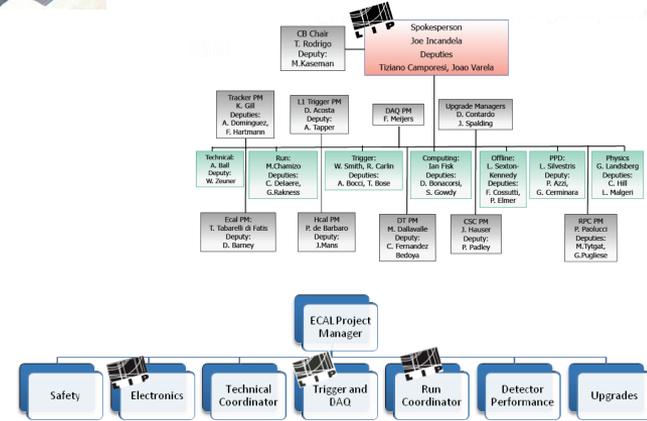
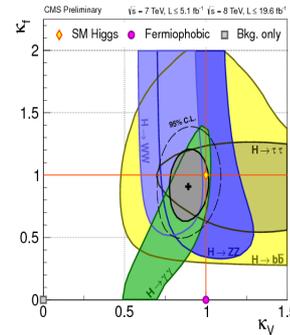
PPS meeting, October 14, 2013



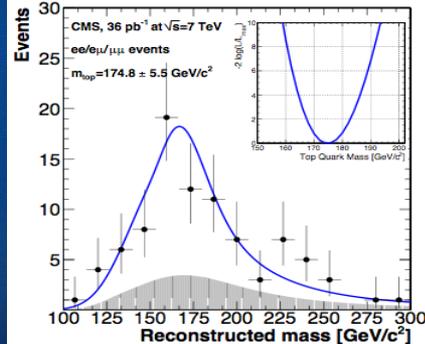
The LIP/CMS group



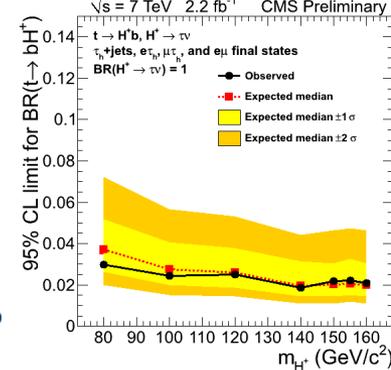
Higgs $\gamma\gamma$ and properties



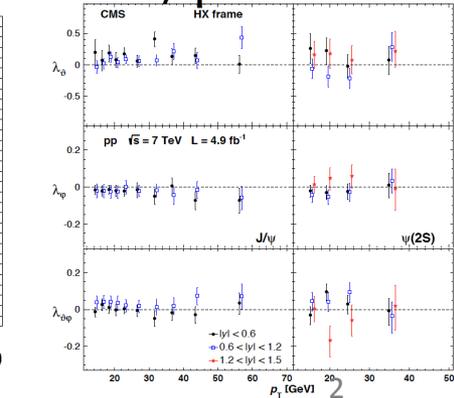
Top quark physics



Charged Higgs in taus



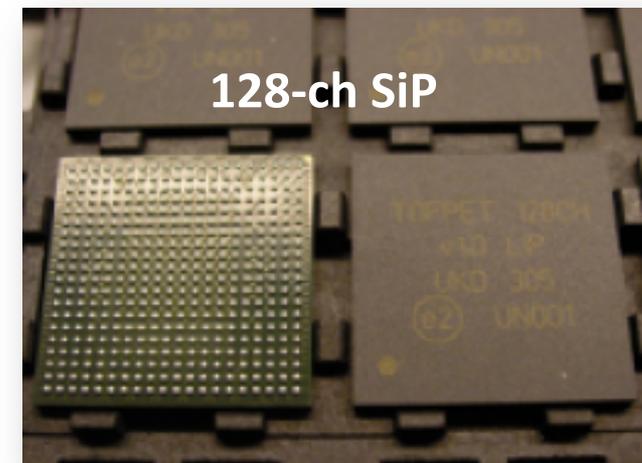
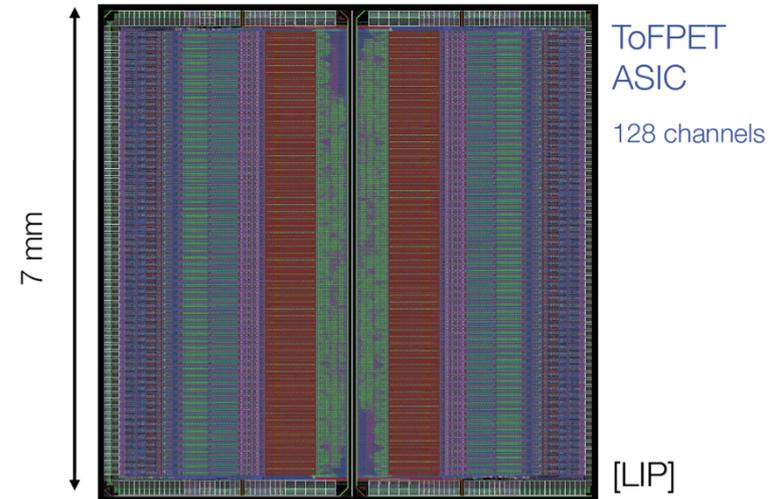
J/ψ Polarization

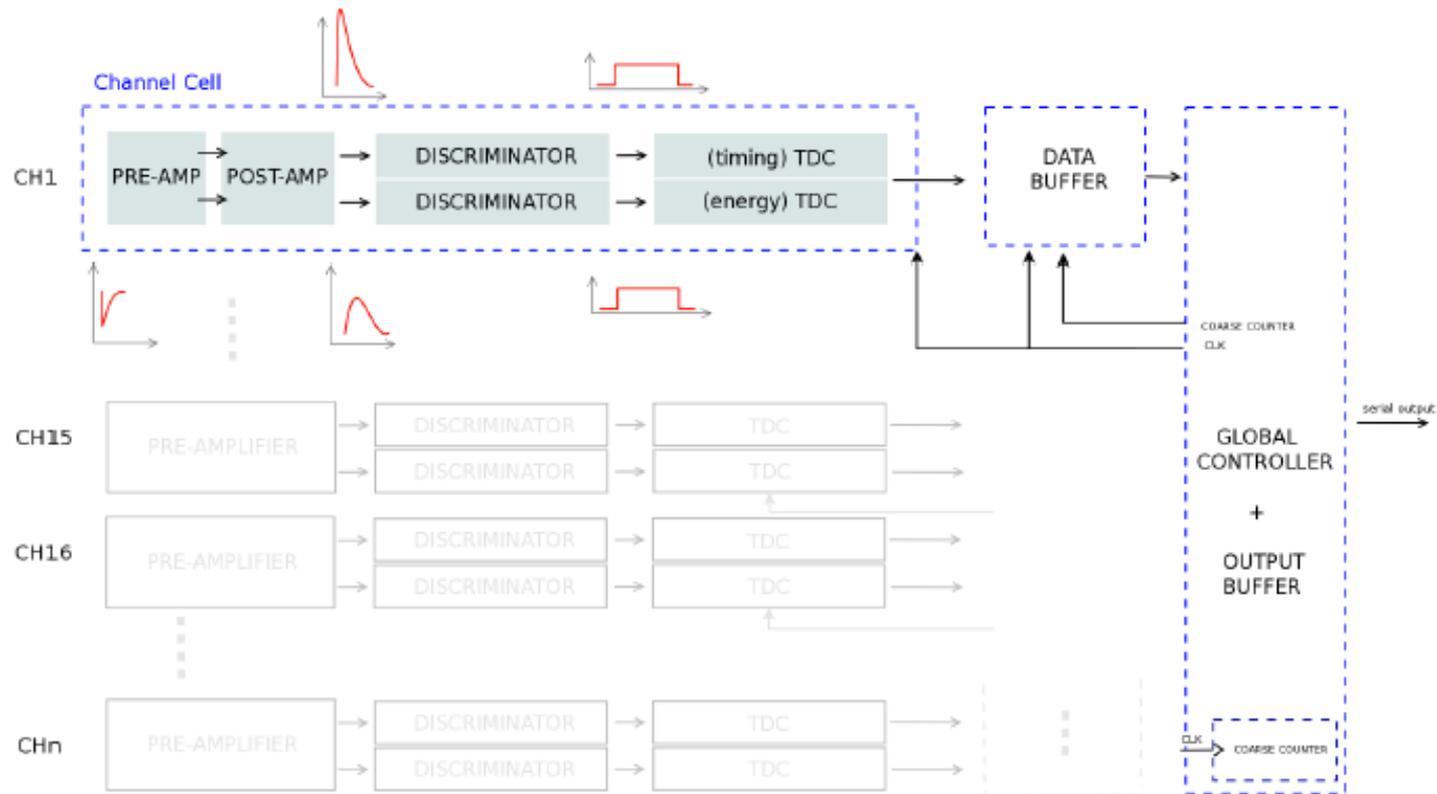


- TOFPET ASIC developed by LIP in the FP7 project EndoTOFPET-US
 - collaboration with INFN Torino
- PET time-of-flight detector plate (~4000 channels)
- MPPC (16-channel arrays, 3x3 mm²) and LYSO crystals
- Coincidence time resolution (CTR) ~200 ps (FWHM)
- Single photon time resolution (SPTR) ~100 ps

ToFPET 128-ch SiP:

- IBM 130nm
- Time measurement with 25 ps resolution
- Analog Frontend + TDC + Digital readout
- SiPM bias tuning
- Single-ended input
- Low power (<10 mW channel)
- Available in 128-ch SiP (two 64-ch chips)

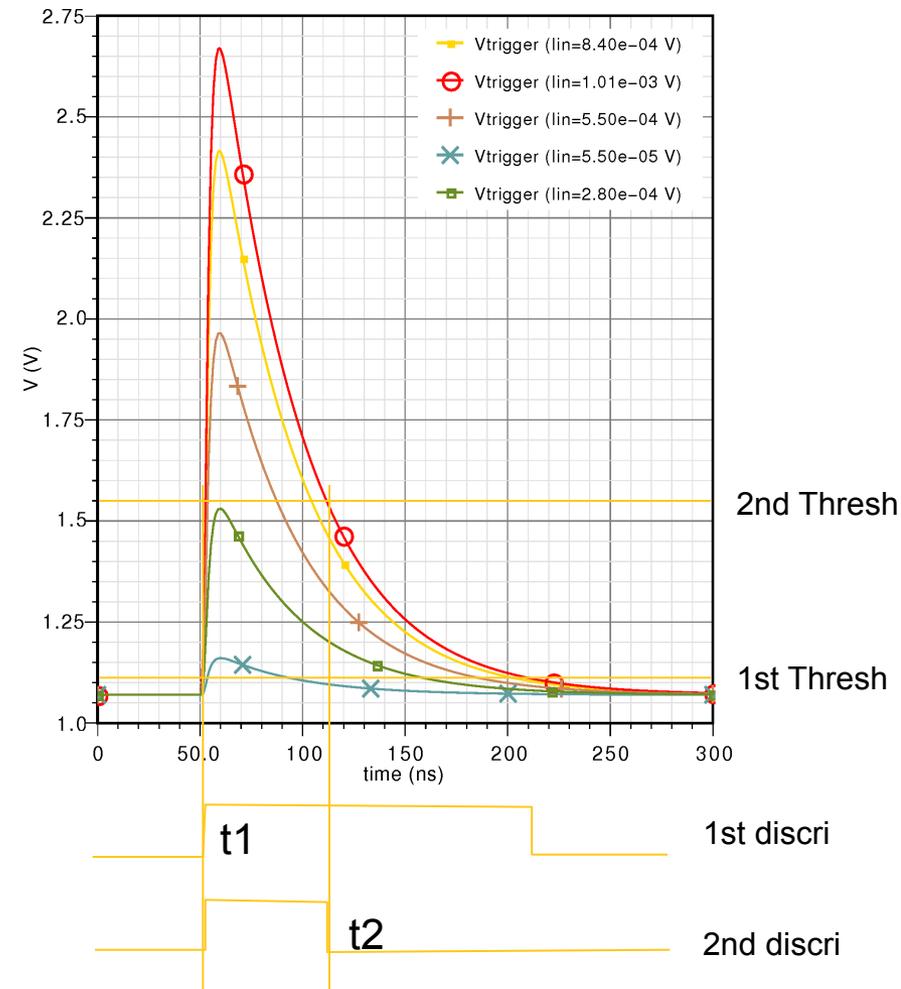




- Two transimpedance amplifier (TIA) stages: two replicas for time and energy measurement (trigger, shaped signals)
- The low noise front-end allows setting the threshold of the discriminator at 0.5 photoelectrons for the time stamp

Time and amplitude measurement

- Optimized for the time measurement of the first photoelectrons
- Threshold for time measurement adjustable in the range 0.5-15 p.e..
- The TDC time binning 25 or 50 ps
- Time-over-Threshold (ToT) using second discriminator
- Second discriminator used also for pulse selection.

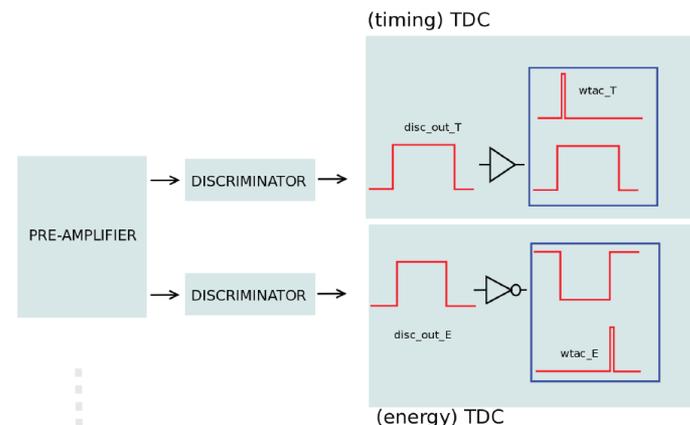
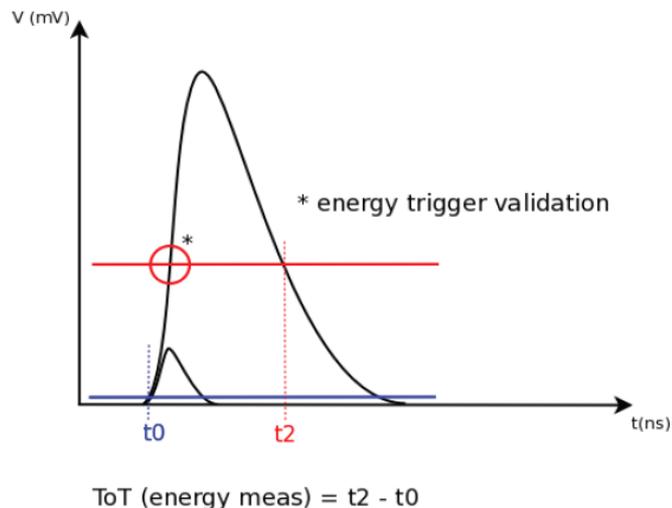


Analogue TDCs generate the time information for two time stamps

Time multiplication (x 128):

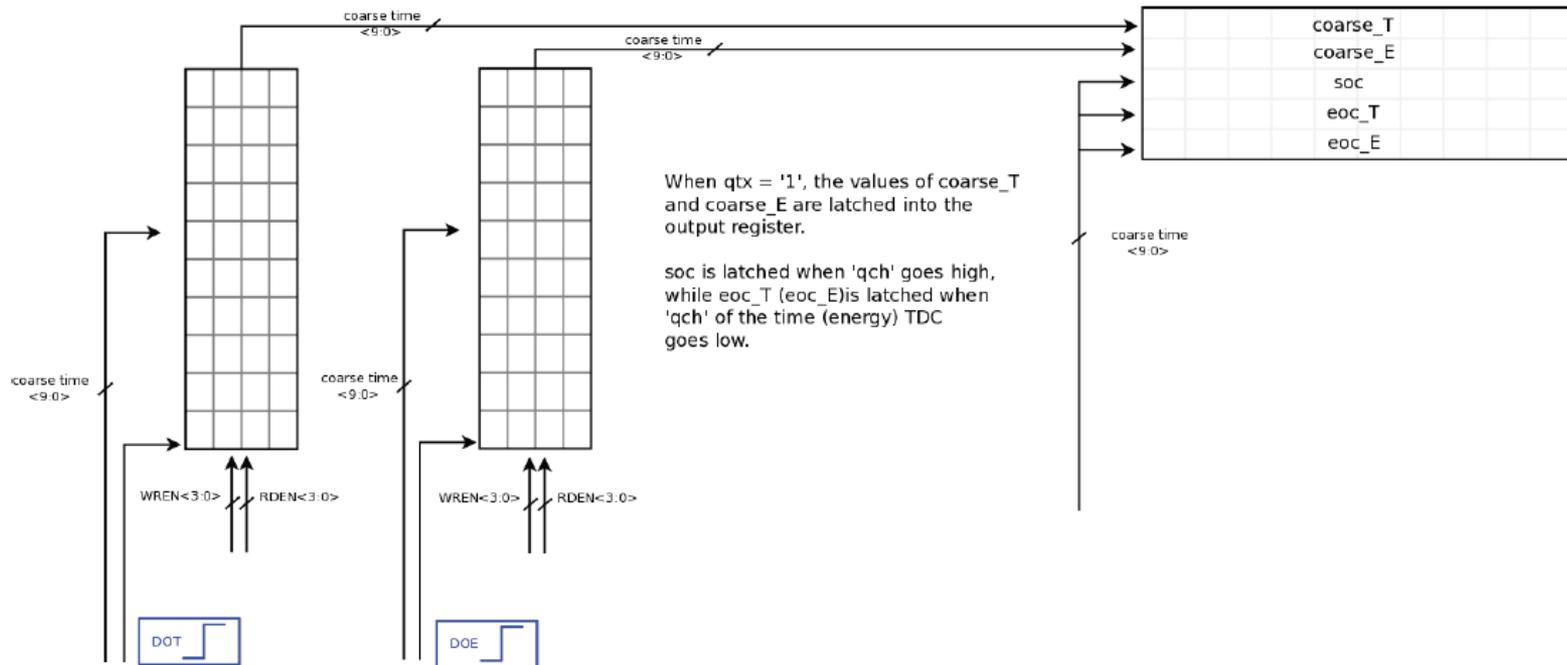
- Charge a buffer capacitor in time between the pulse and the clock edge
- Transfer the stored charge into a 4x bigger capacitor
- Discharge the large capacitor with a 32x smaller current.
- Measure discharge time with 160 MHz clock
- 50ps or 25 time binning (configurable)

Based on Torino design for NA62



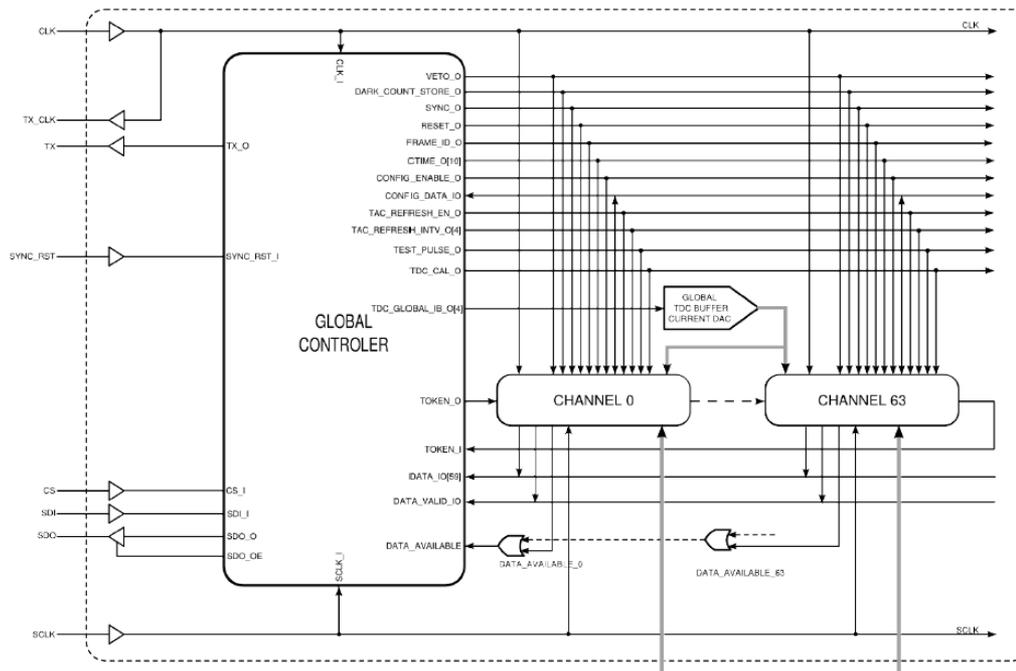
Channel derandomizer

- Four TAC per channel
- Multi-buffering FIFO

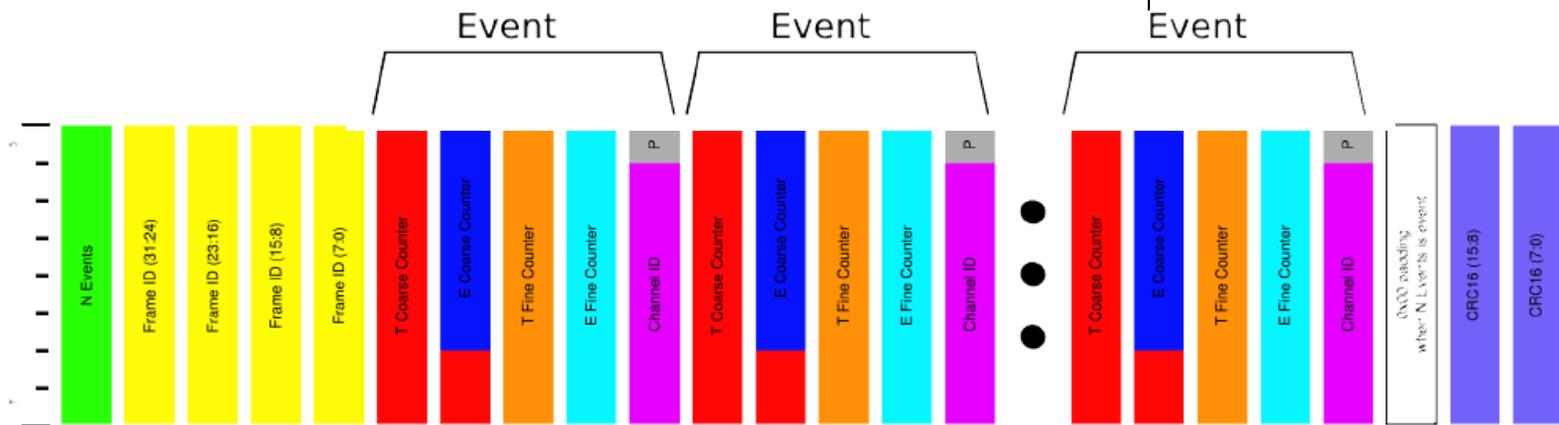
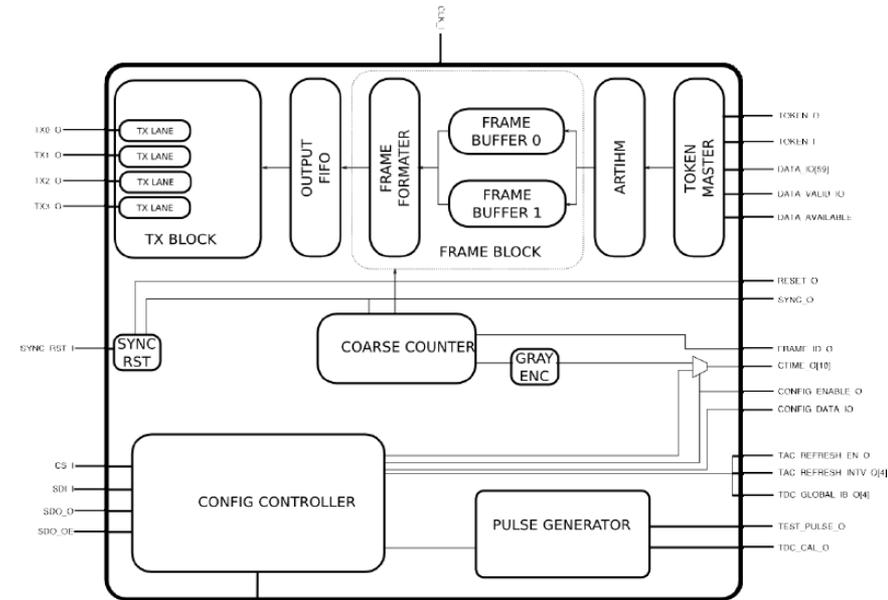


Configuration and monitoring

- Chip & channel configuration from configuration link
- Monitoring dark count rate per channel



- 160 MHz LVDS
- 8B/10B encoded
- Source synchronous
- Variable width: 1 or 2 bits
- Data encoded in frames (6.4 us)
- Max output rate 320 Mb/s



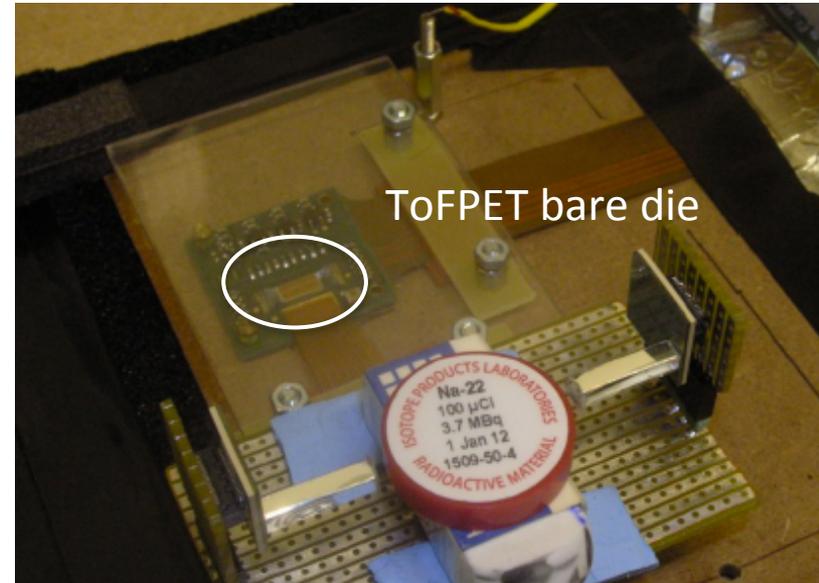
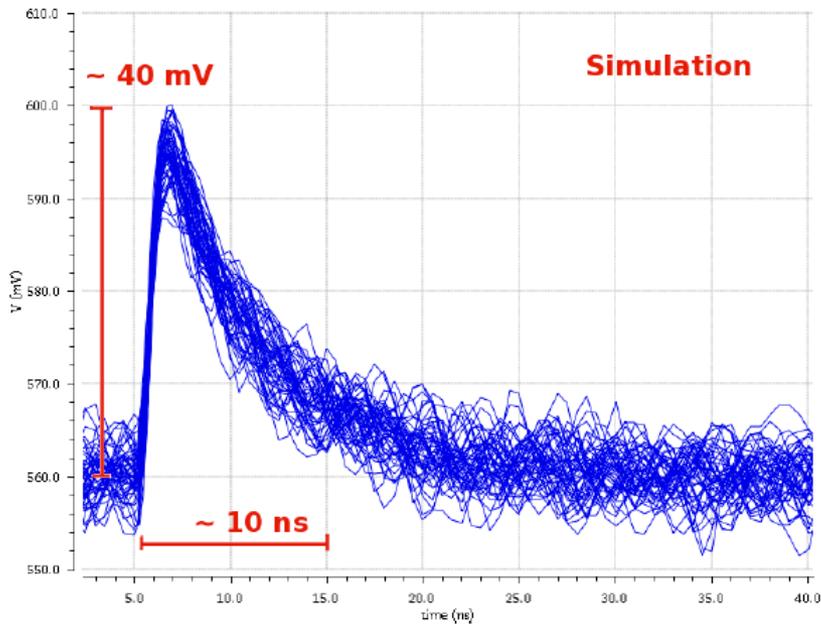


ToFPET chip specs

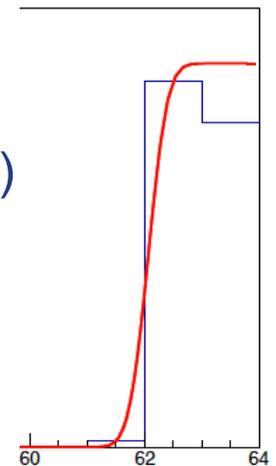
- Number of channels 64
- Clock frequency 150 - 200 MHz
- SNR ($Q_{in} = 100 \text{ fC}$) > 15
- Amplifier noise (in total time resolution) $< 25 \text{ ps}$ (FWHM)
- TDC time binning 50 or 25 ps
- Max. output data rate 320 Mb/s
- Channel masking programmable
- SiPM bias adjustment 500 mV
- Calibration internal pulse, 5-bit prog. amplitude

Single photon pulse and noise

Single photo-electron



- Simulated noise (for 300 pF input capacitance) 2.6 mV (rms)
- Noise measured from s-curve (2-3 mV)
- Threshold 1 p.e. ~20 mV

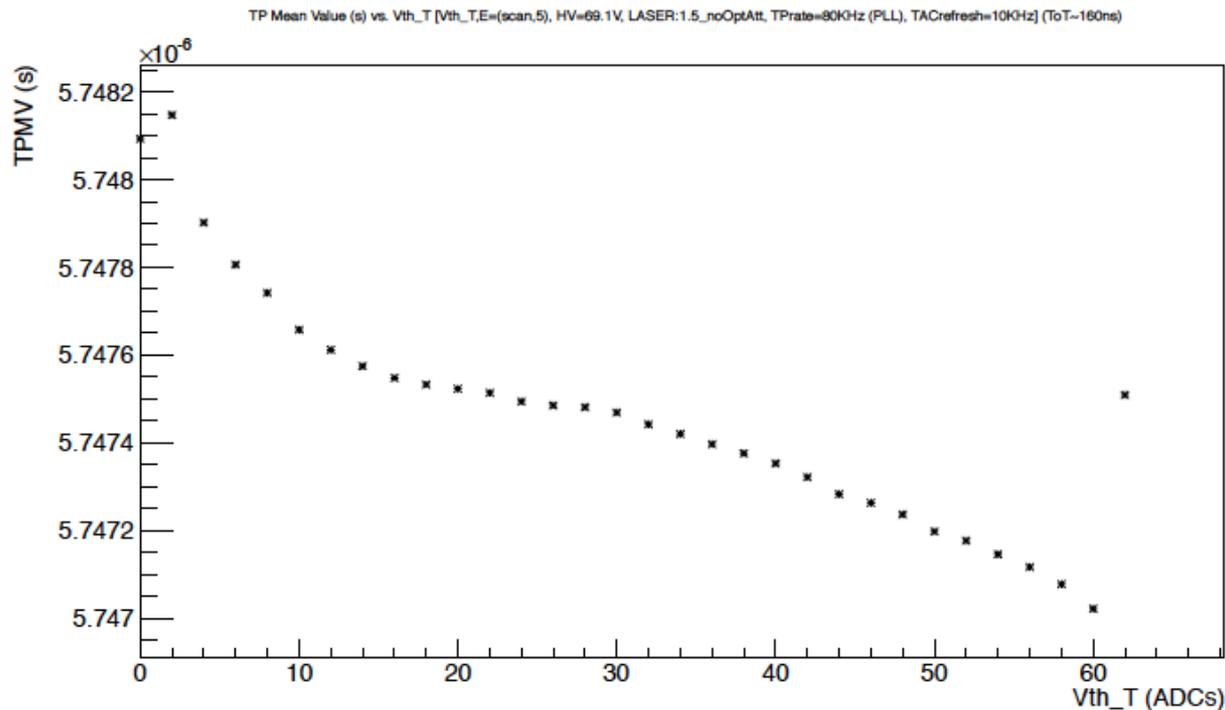


Slew rate for a laser pulse

Pulse slew rate at time discriminator input:

- Test Pulse (from laser) → Slew-rate = 850mV/ns
- Simulation: 200 pC delta current pulse → 900mV/ns

Mean Value vs. V_{thT} (LSB x-axis = 10 mV)



Bare die test setup

MPPC discrete TSV arrays (3x3 mm²)

PicoQuant Laser

- MPTR: LI=1.5, no optical attenuator (Nph > 1000)
- SPTR: LI=7.5, WITH optical attenuator (Nph = 1)

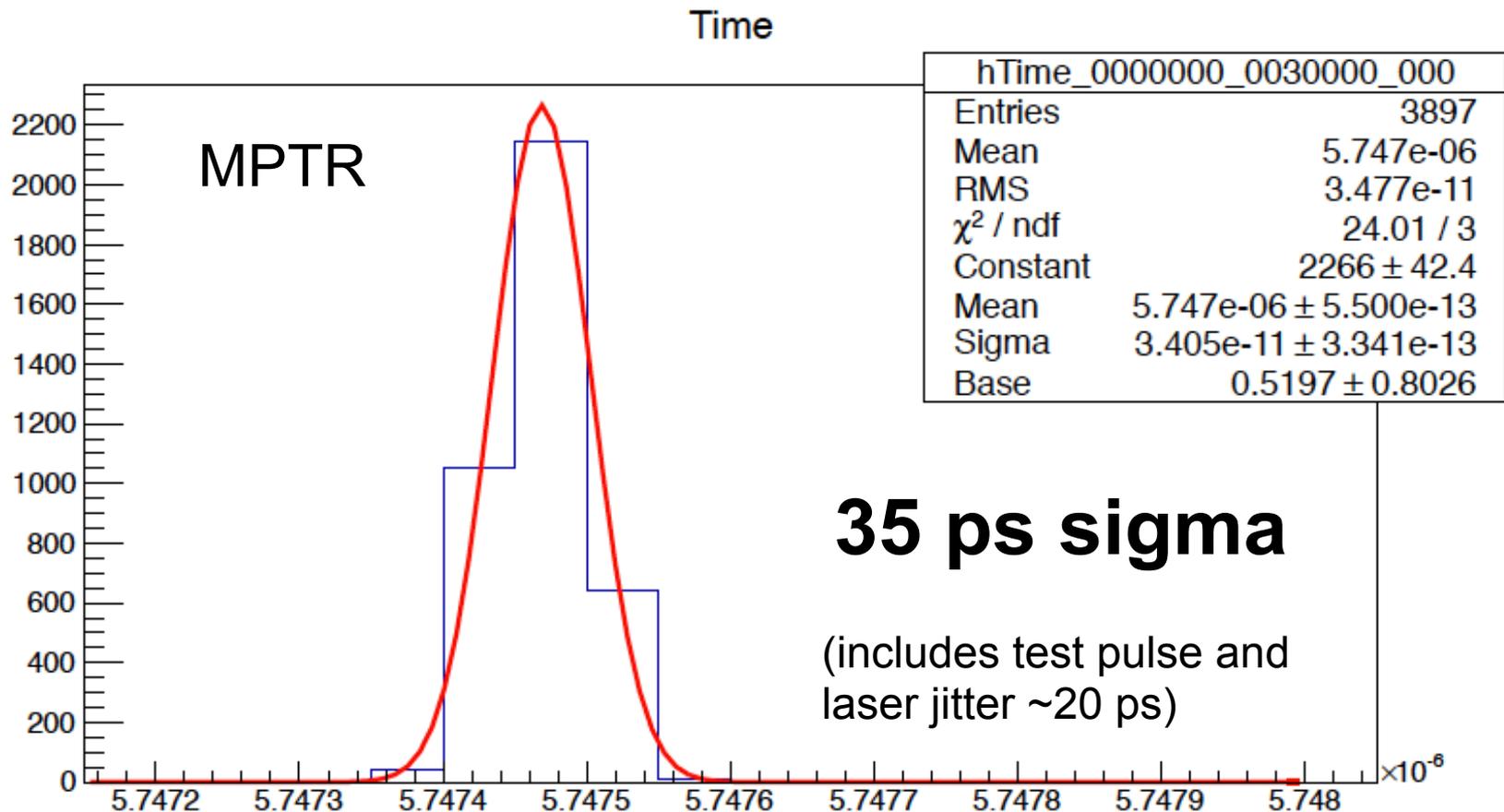
Nominal test conditions:

- T = 18-20 C
- 160 MHz, DVDD=1v5
- TP rate = 80 KHz
- $V_{thT} = 20\text{mV}$
- $V_{thE} = 550\text{mV}$ (MPTR)
- $V_{thE} = 20\text{mV}$ (SPTR)

Multi-photon time resolution

PicoQuant Laser

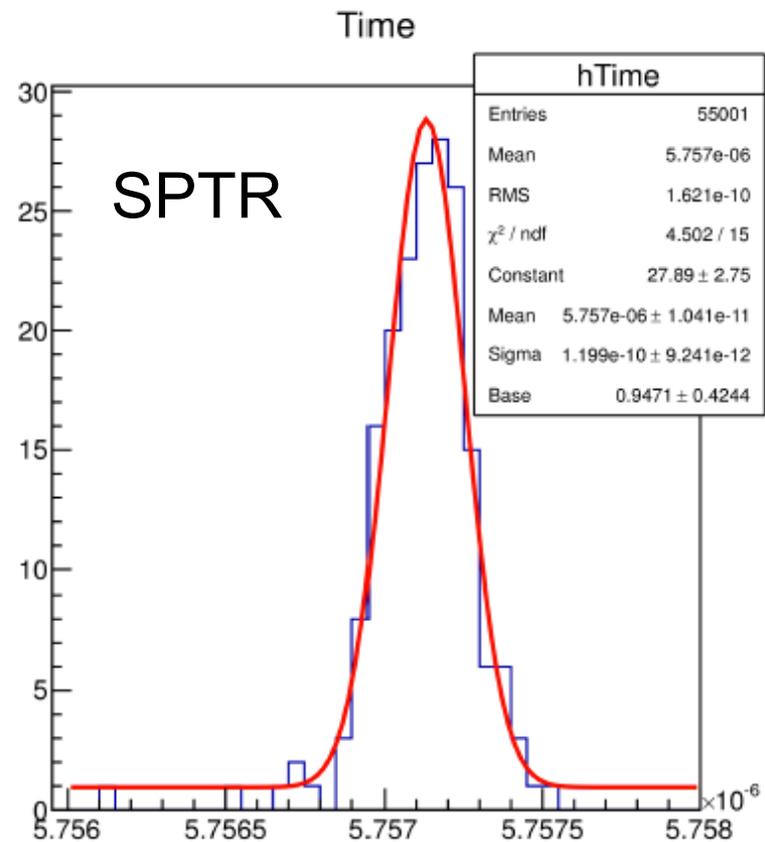
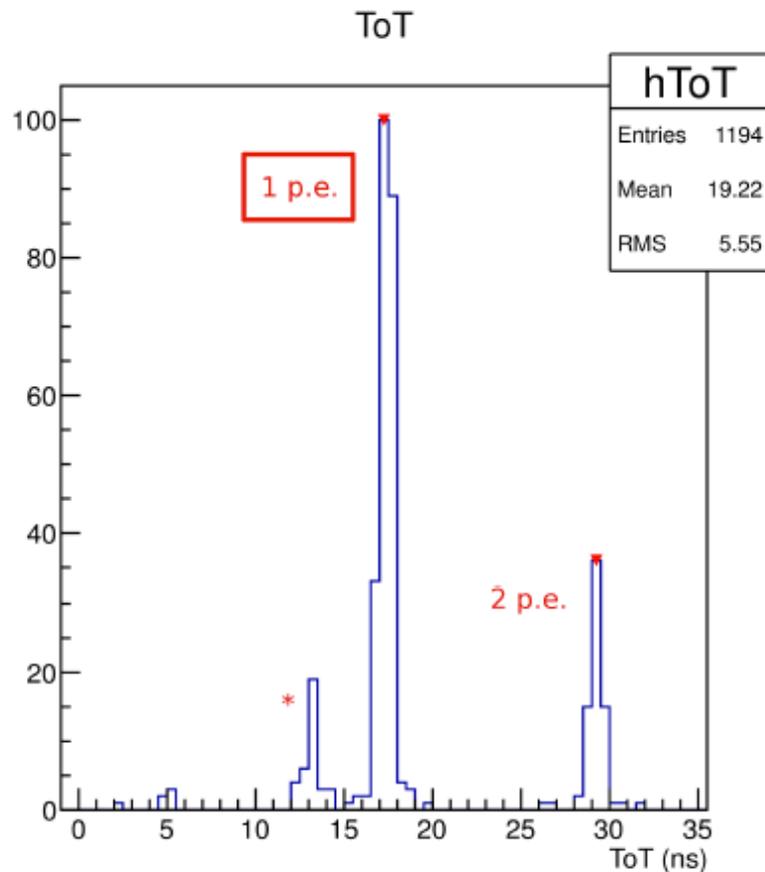
no optical attenuator ($N_{ph} > 1000$)



Single photon time resolution

PicoQuant Laser

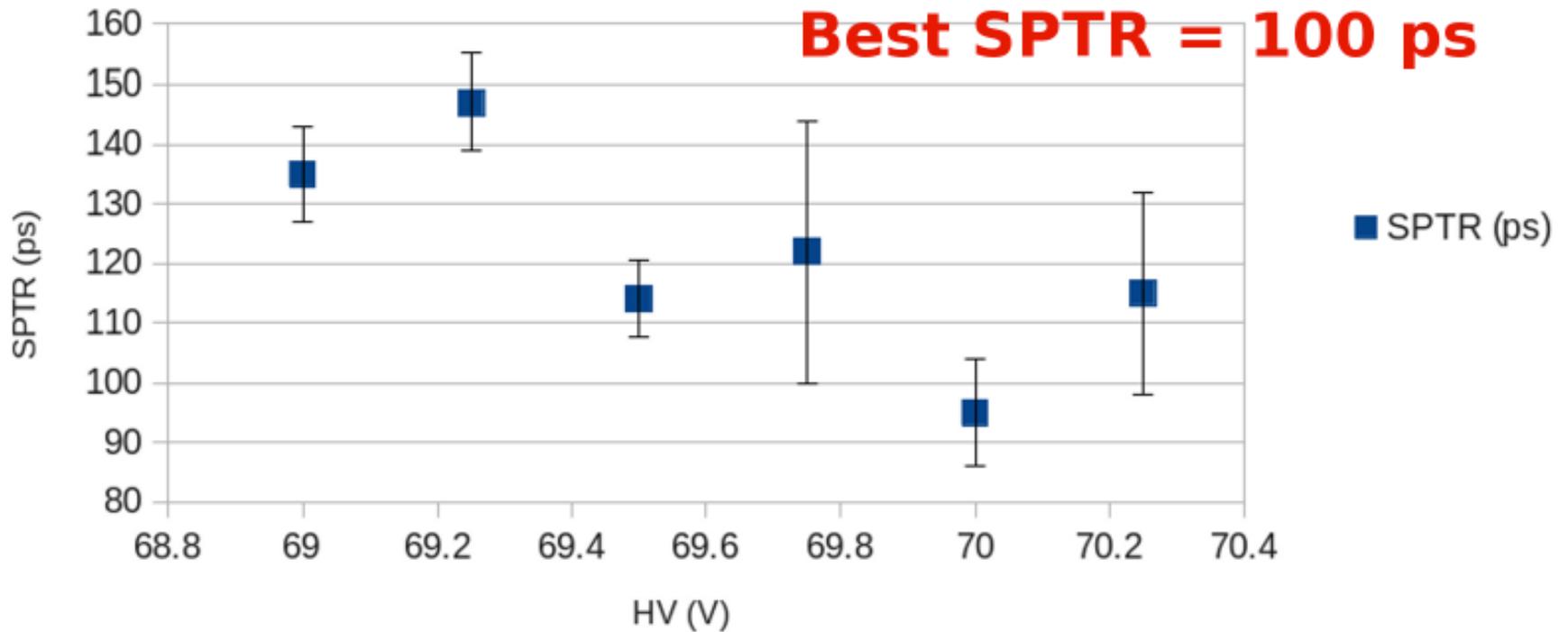
with optical attenuator (average $N_{ph} = 1$)



SPTR vs bias voltage

SPTR sigma (ps) vs. HV

ToT selection 1 p.e., T=19°C, MPPC SN27-B4



- ToFPET v2.0 under development
- New technology (110 nm)
- Time resolution 10 ps
- Rate per channel of several MHz
- Time scale 1 year



Possible use in PPS prototype

- Present ToFPET chip (v1.0) could provide a fast track towards MPPC readout with ~ 30 ps time resolution (MPTR)
- Coupling one MPPC channel to 4 ToFPET channels could allow multi-threshold operation
 - Improved time resolution
 - 20 QUARTIC bars fit in one 128-ch chip
- DAQ hardware and firmware is available
- ToFPET v1.0 chip and system rate capability adequate for low-luminosity runs. ToFPET v2.0 would be needed high-luminosity runs.
- Interface to L1 trigger to be implemented in FPGA firmware