Imperial College London

First results of T2K-nd280 Front End Electronics performance with GM-APDs

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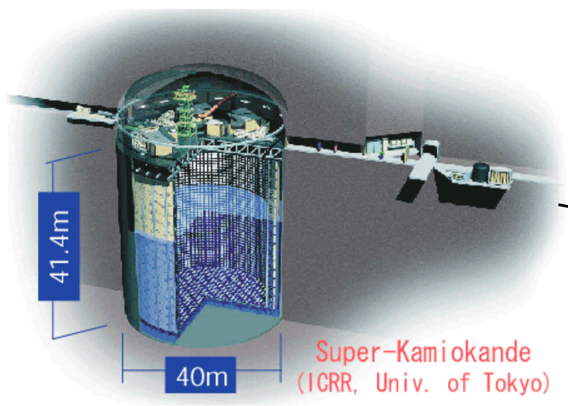
for the T2K-UK electronics and photosensors groups

Outline

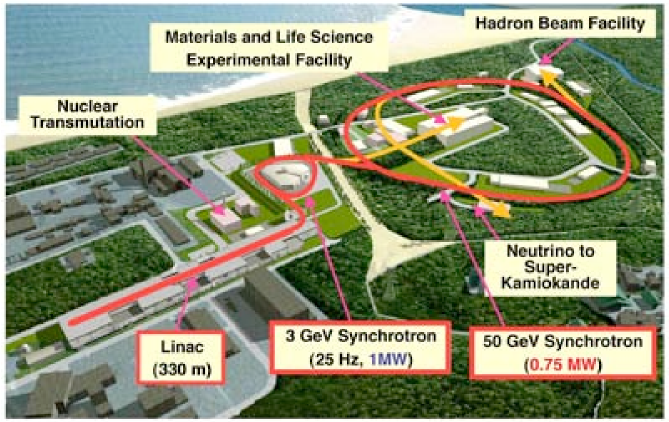
- ➡ T2K and the 280m near detectors
- ➡ overview of the Trip-t Front End Board (TFB)
- ➡ Measurements with MPPC 100/400 pixels
    - Charge spectra
    - Timestamping
    - Voltage trim functionality tests

Tokai to Kamioka

12 countries, 62 institutions, ~ 350 people

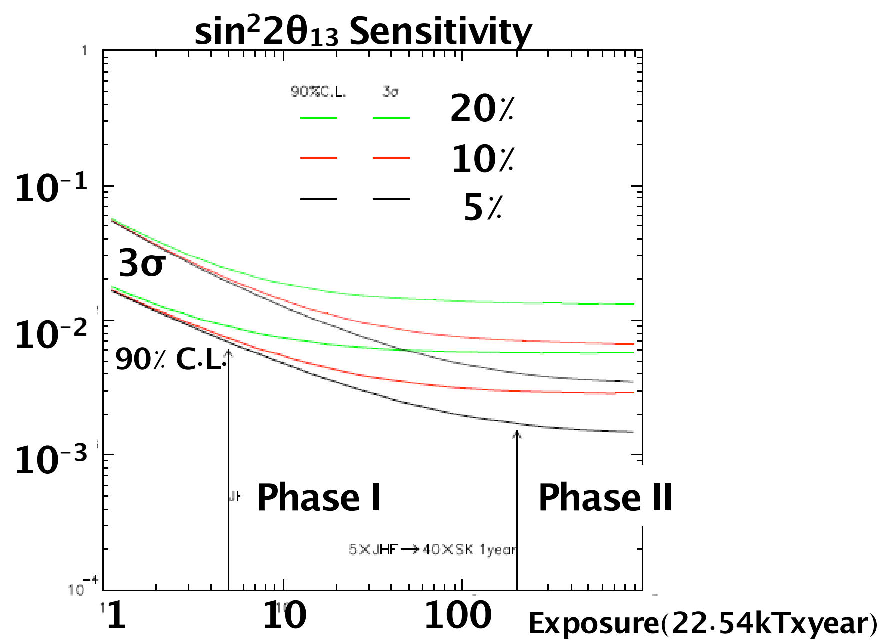


Far detector : Super Kamiokande



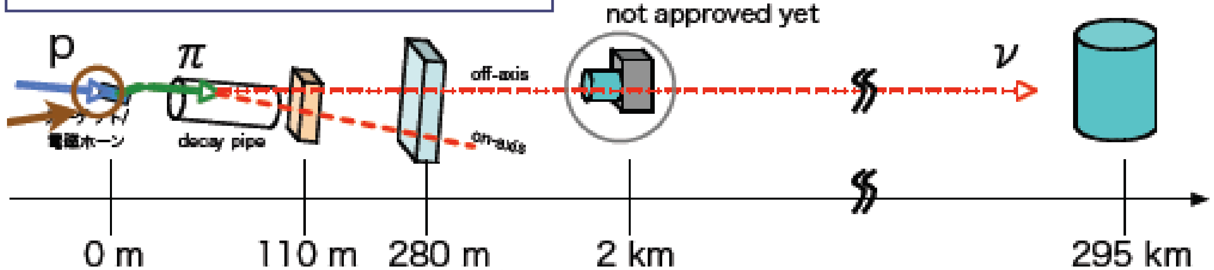
ν beam : J-PARC facility

- ➡ 2009 Phase I : $\theta_{13}, \theta_{23}, \Delta m^2_{23}$
  - J-PARC : **0.75 MW** 30 GeV
  - SK-III : **22.5 kT** FV, **full PMT coverage**
- ➡ 2015 Phase II : θ_{13}, δ_{CP} ?
  - J-PARC : **4MW** 50 GeV
  - HyperK : **1 MT scale**

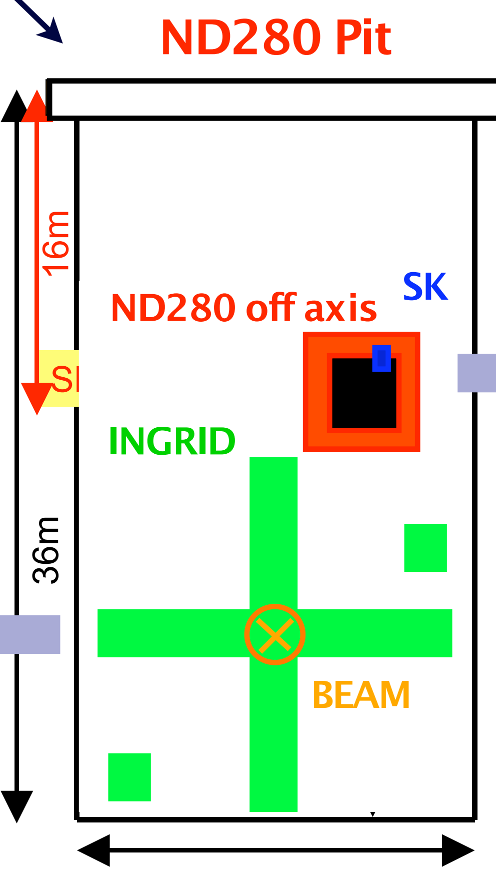


280m near detectors complex

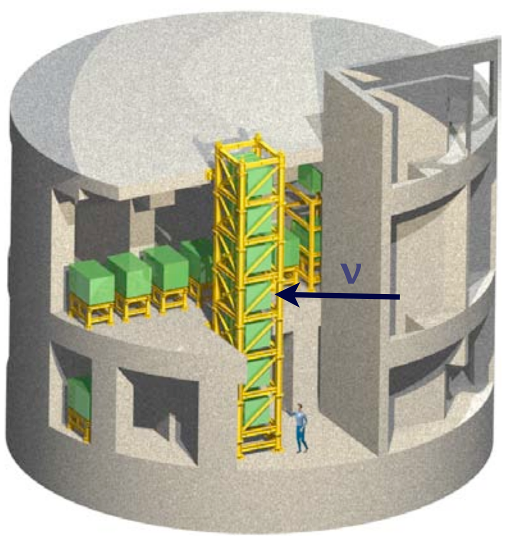
T2K baseline

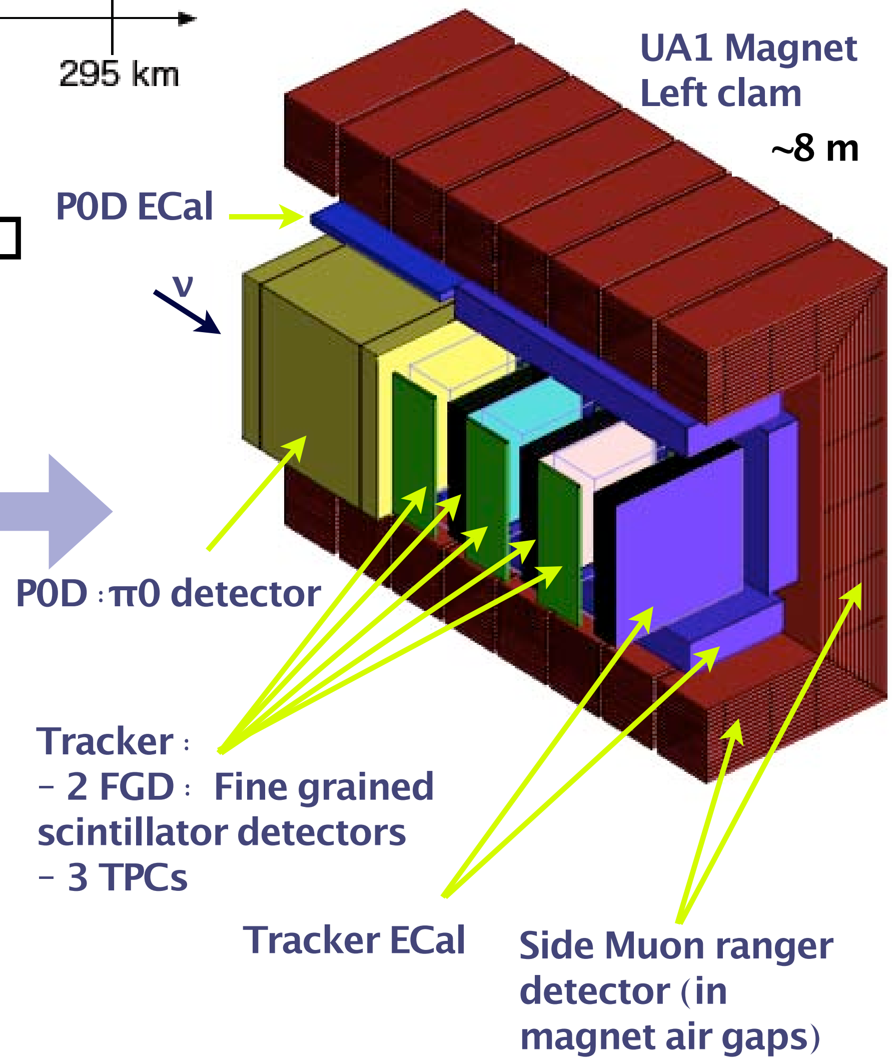


ND280 : off axis beam flux and SuperK backgrounds measurements



INGRID : on axis neutrino flux measurement





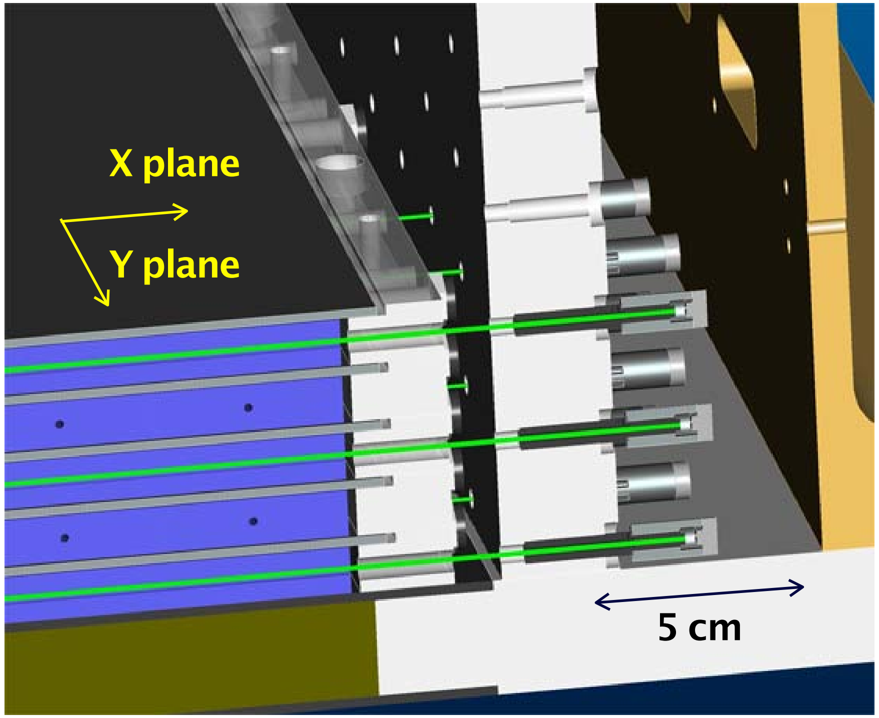
Scintillators readout constraints

- Magnetic field
  - UA1 magnet will be operated at B = 0.2 T
- Low light yield
  - In scintillators sub-systems ~ 10-15 p.e./MIP/cm expected
- Very tight space constraints
  - small space for readout
- High number of channels
  - ~60000 total
- Detector in operation for 5 years
  - Low maintance is desirable

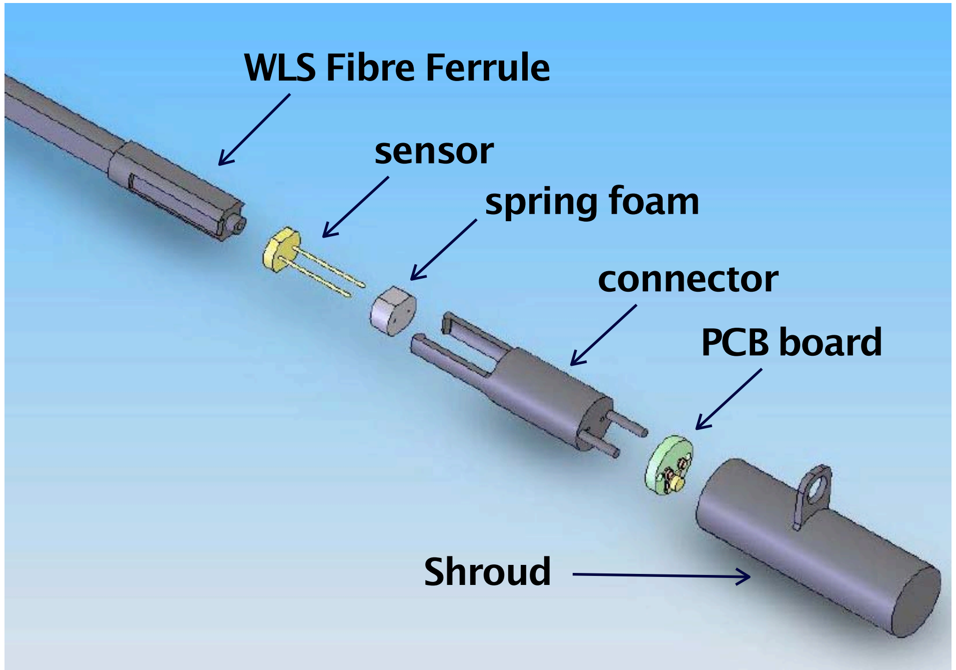
- GMAPD is only candidate that met (almost) all requirements

Scintillators Readout

Scintillator bar readout cut view (ECAL)

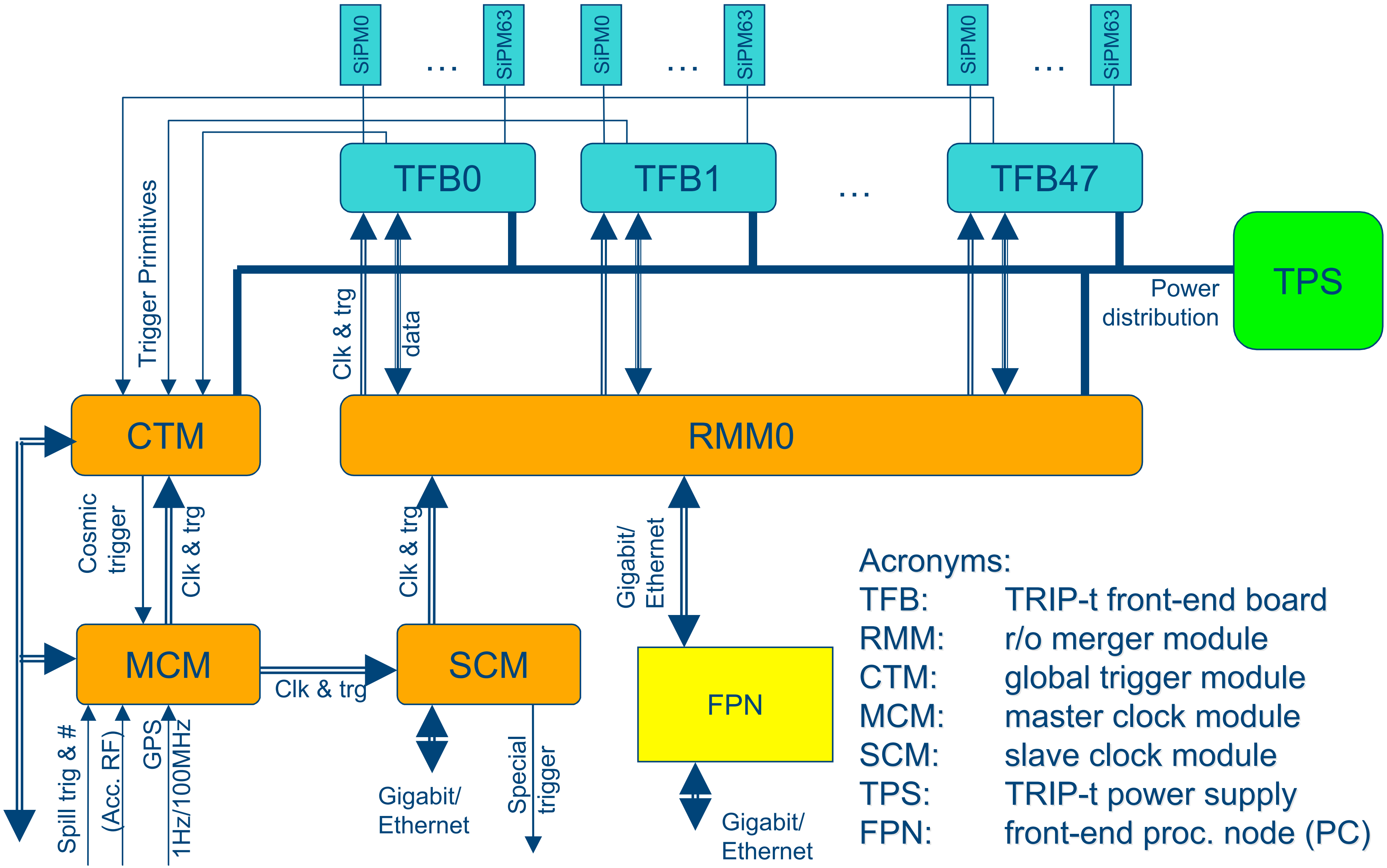


Connector design for P0D/ECAL



- ➡ Scintillator + Wavelength shifting fibre + GMAPD
  - Kuraray Y-11 1 mm diameter WLS fibre
- ➡ Tight readout space in UA1 magnet
- ➡ GMAPDs have individual connector
- ➡ Good coupling crucial to minimise light loss at fibre end

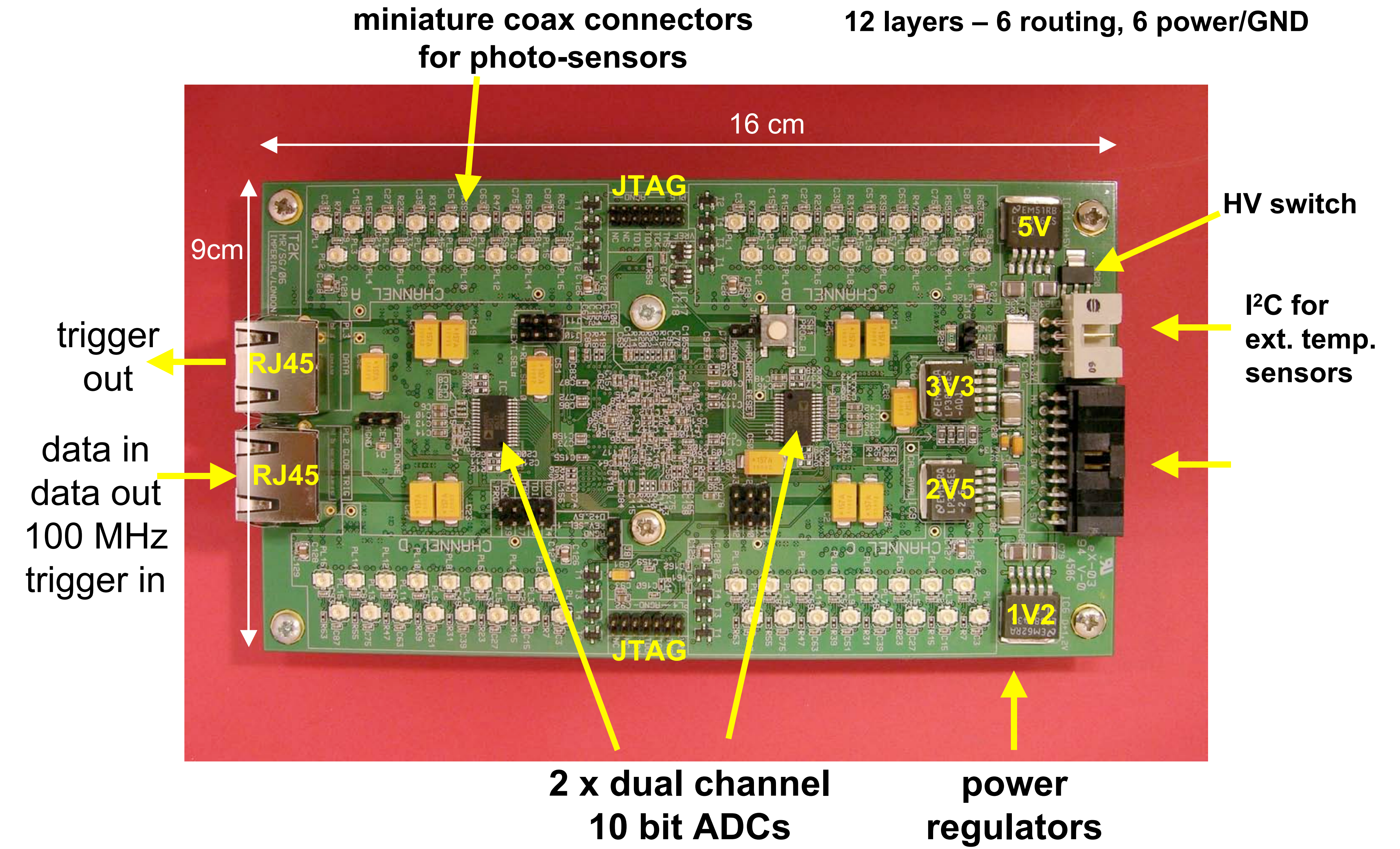
ND280 Electronics overview



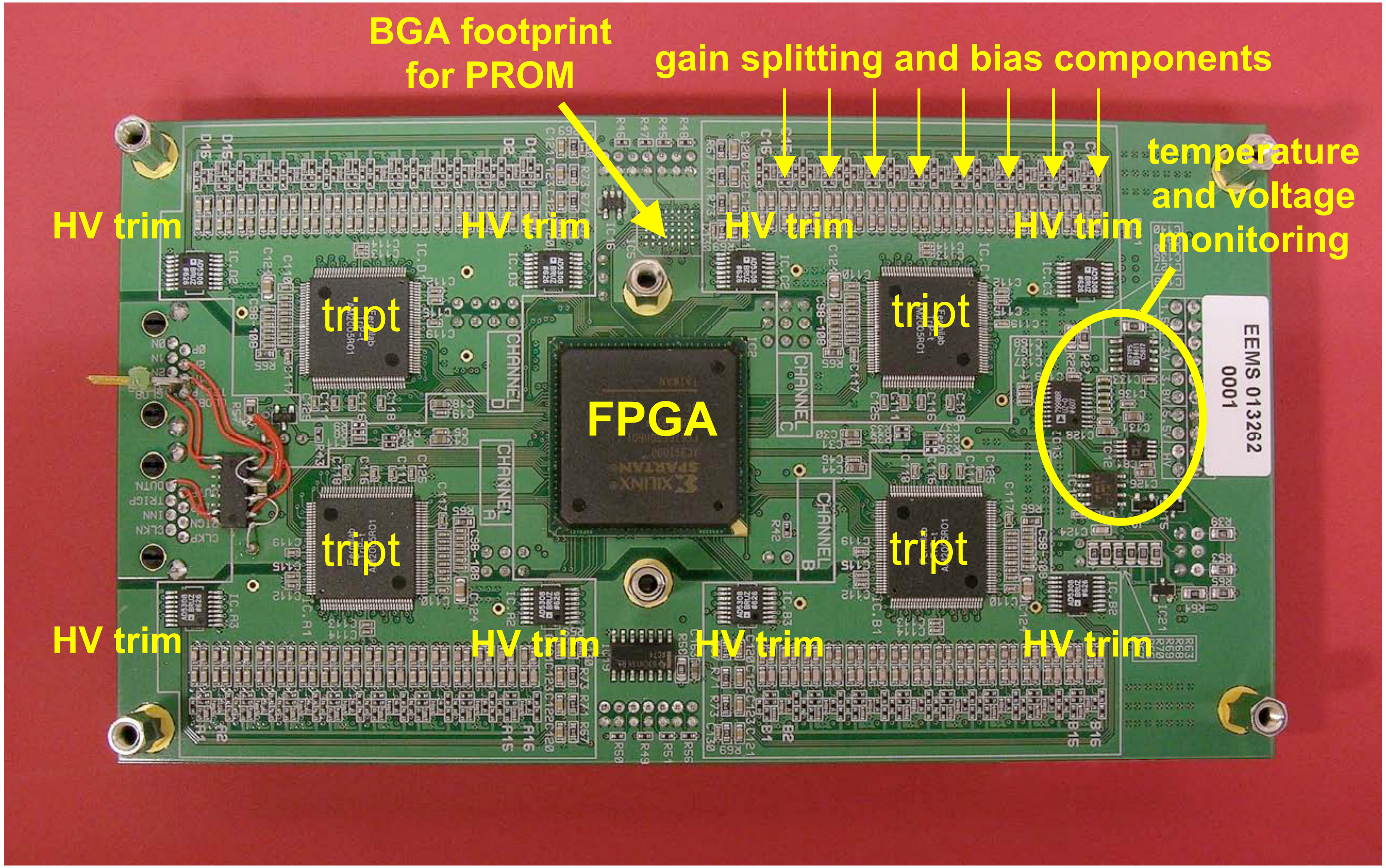
Acronyms:

TFB:	TRIP-t front-end board
RMM:	r/o merger module
CTM:	global trigger module
MCM:	master clock module
SCM:	slave clock module
TPS:	TRIP-t power supply
FPN:	front-end proc. node (PC)

TRIP-t Front end board (front view)



TRIP-t Front end board (back)



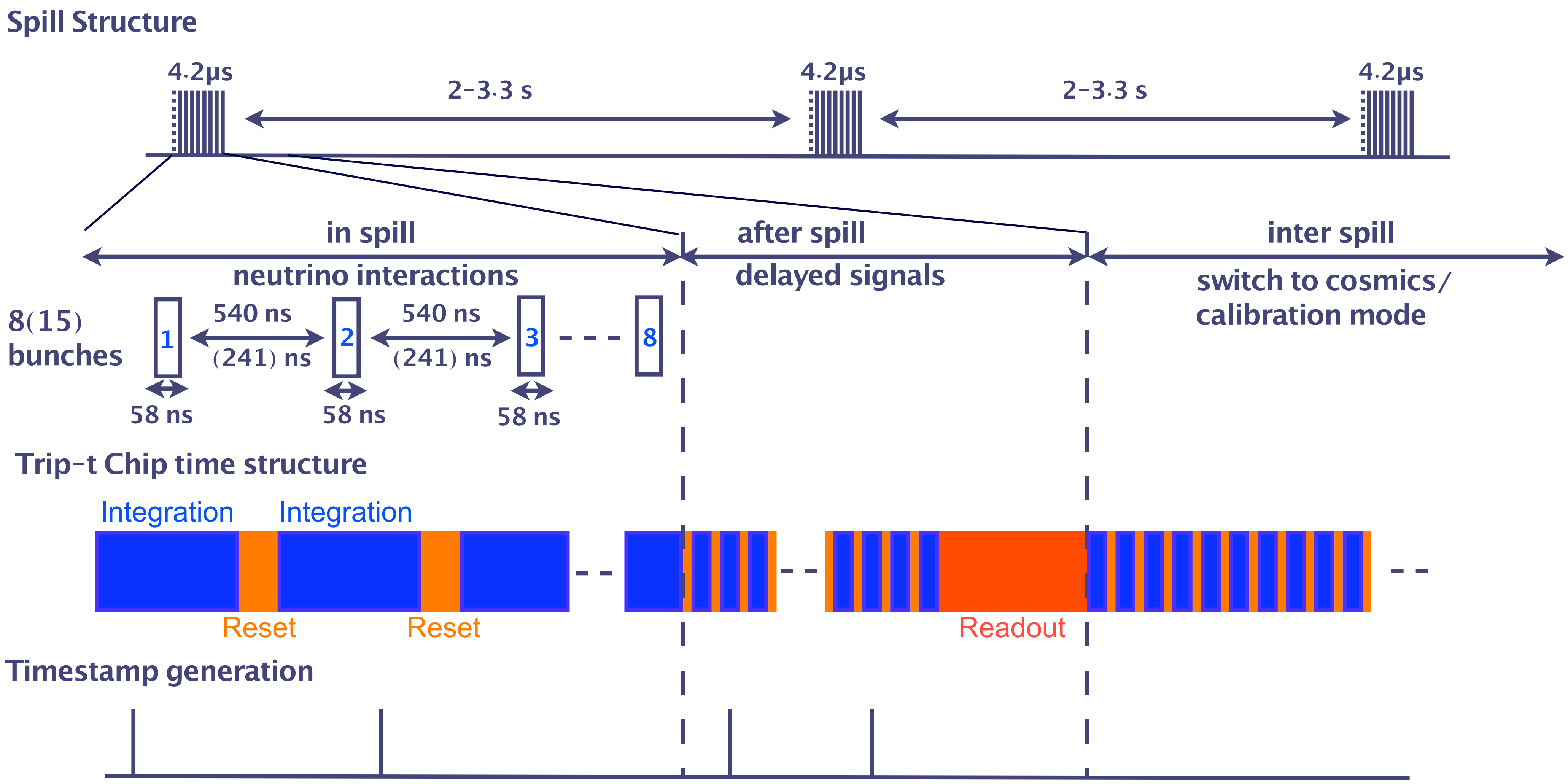
8 x 8 channel HV trim DACs

- 5V trim range on every channel

TRIP-t parameters

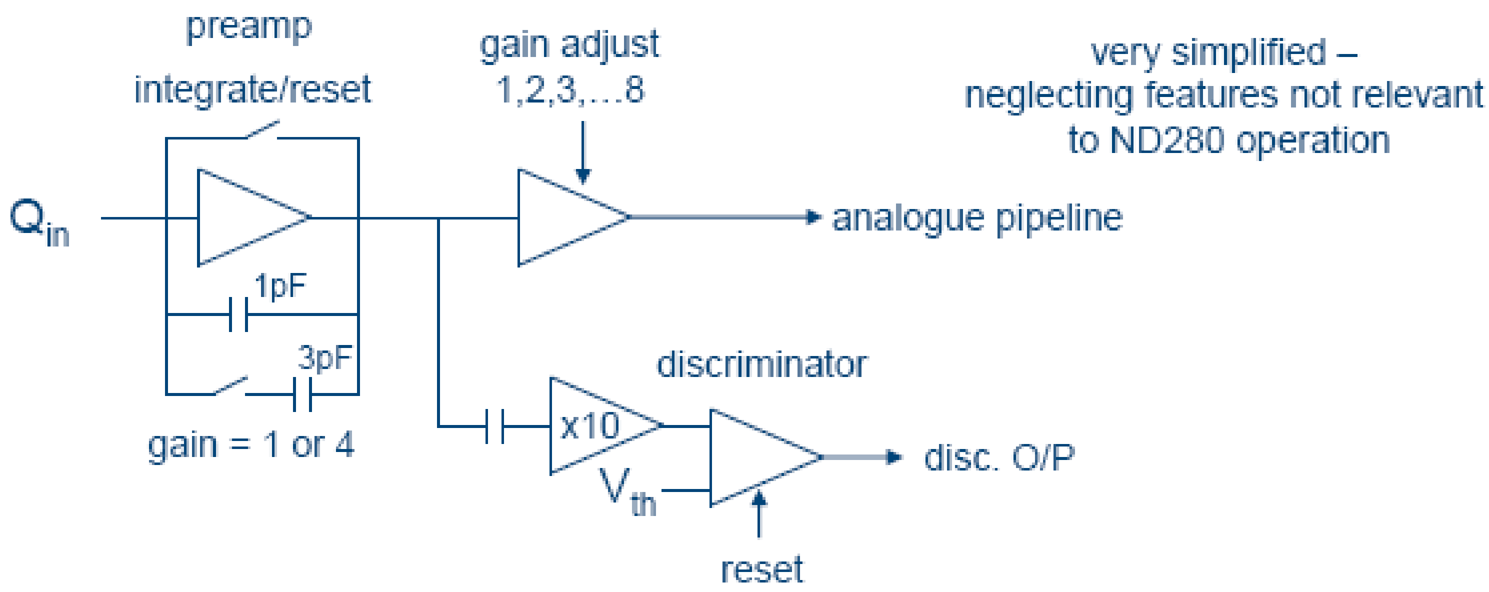
- ➡ 32 synchronous channels
- ➡ Adjustable Integration window
  - 50 nsec to many musec
  - reset time can also be adjusted, 50 nsec minimum
- ➡ Adjustable gain
  - saturation at 3000 fC
  - noise < 1fC
- ➡ Buffer depth 23 timeslices
- ➡ Timestamp discriminator threshold for each TRIP-t
  - 1 timestamp per channel/integration window
- ➡ Timestamp generation from 400MHz TDC (FPGA)
  - **2.5 ns resolution**

J-PARC Spill structure



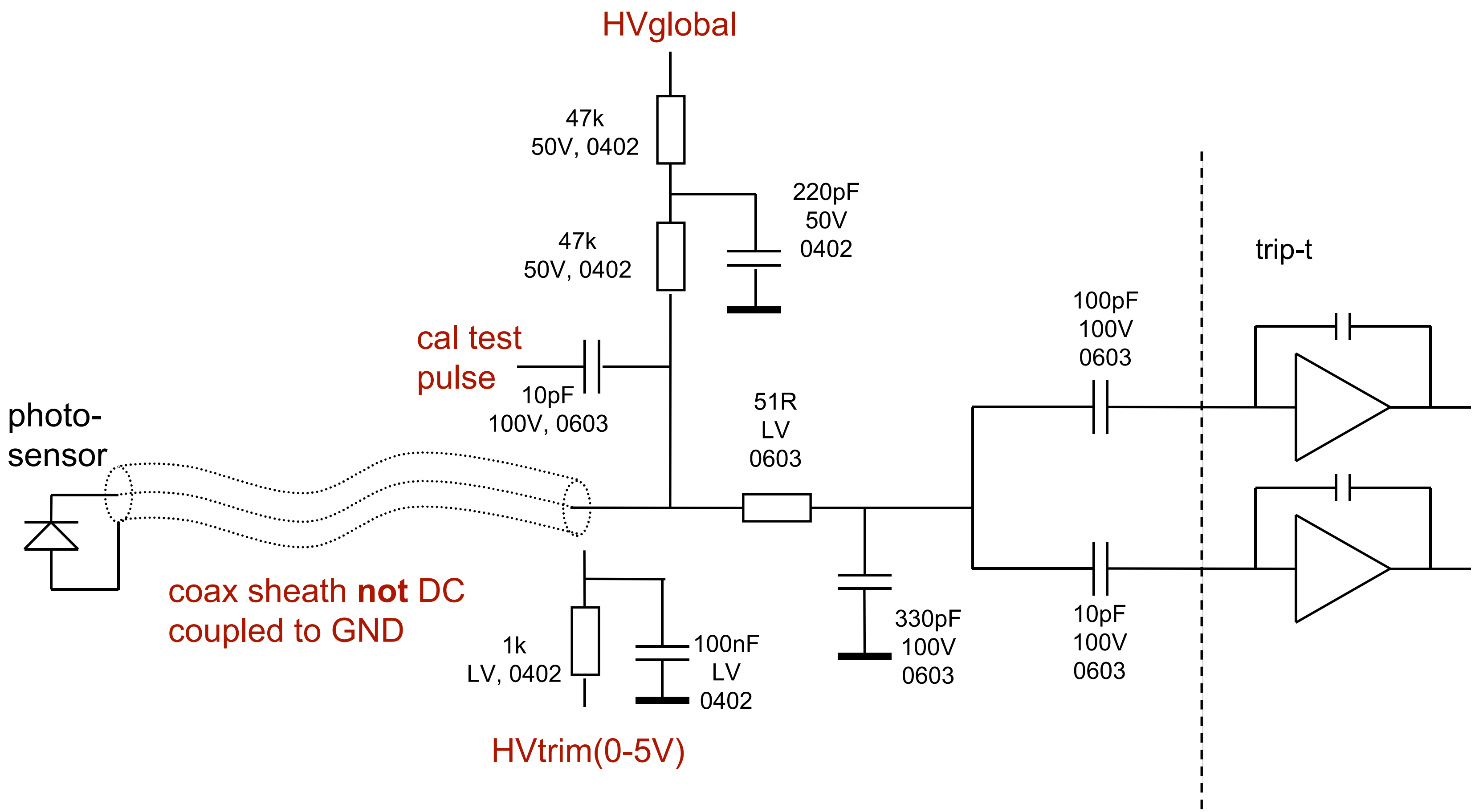
- ➡ 8(15) bunches per spill
- ➡ 4(2) muon lifetime after spill active period (90(80)% active)
  - translates to 50-70% in Michel electron tagging efficiency

TRIP-t front end



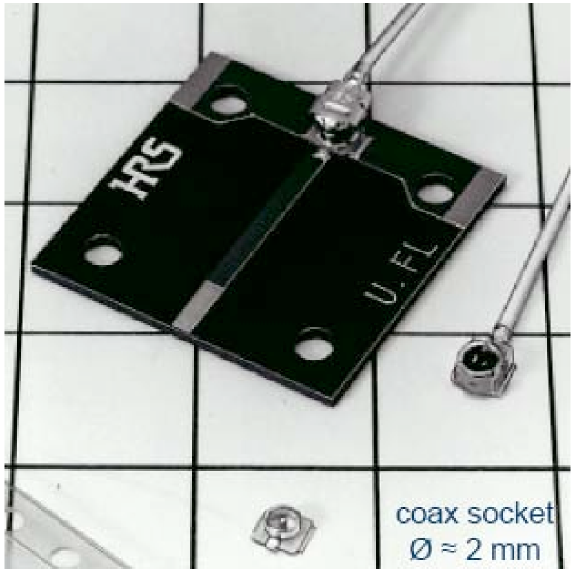
- ➡ Only pre-amp affects signal feeding discriminator
  - no fine control (x1 or x4)
- ➡ discriminator threshold Vth
  - common to all channels on chip
- ➡ Analogue bias settings
  - gain, Vth, etc
  - programmable via serial interface

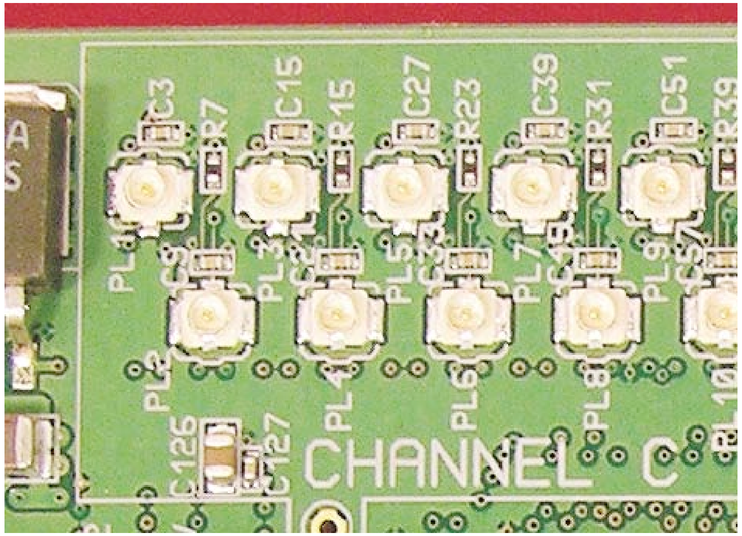
GMAPD-TFB connection



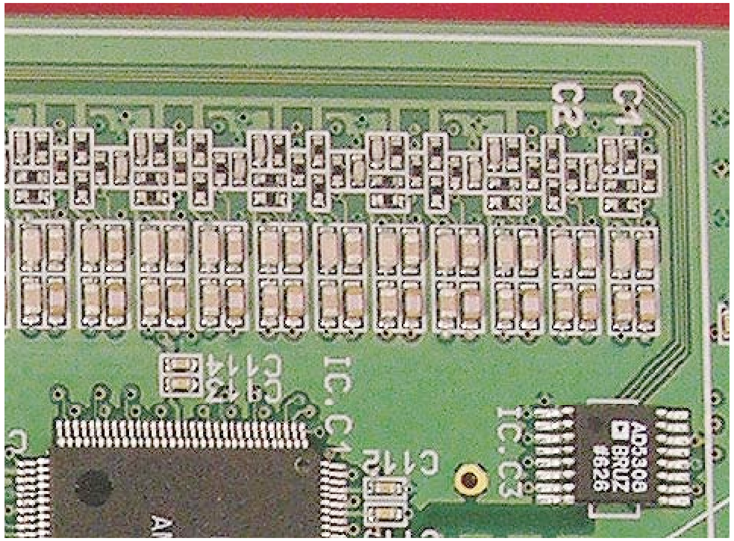
- HVglobal : common to all GMAPD channels on the TFB
- HV Trim : 5V individual bias voltage adjustment
- HV Trim applied to coax sheath – AC coupled to GRD

Interconnections

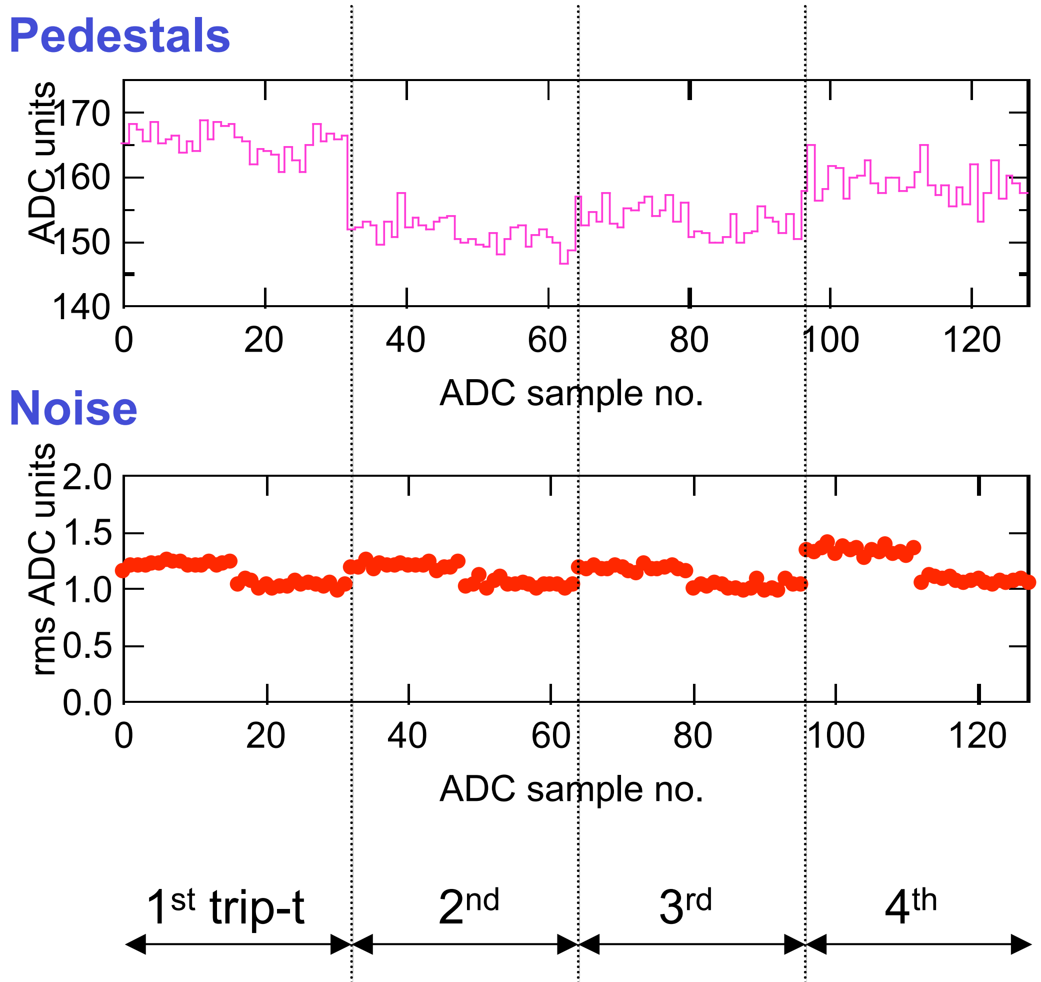




- Miniature coaxial cable (HRS)
  - stands voltage input up to 100V
- min coax connectors on top surface
- Gain splitting and bias components on bottom surface
- Electric fan-in to TRIP-t inputs on internal layer to avoid pick-up



TFB Pedestal and noise



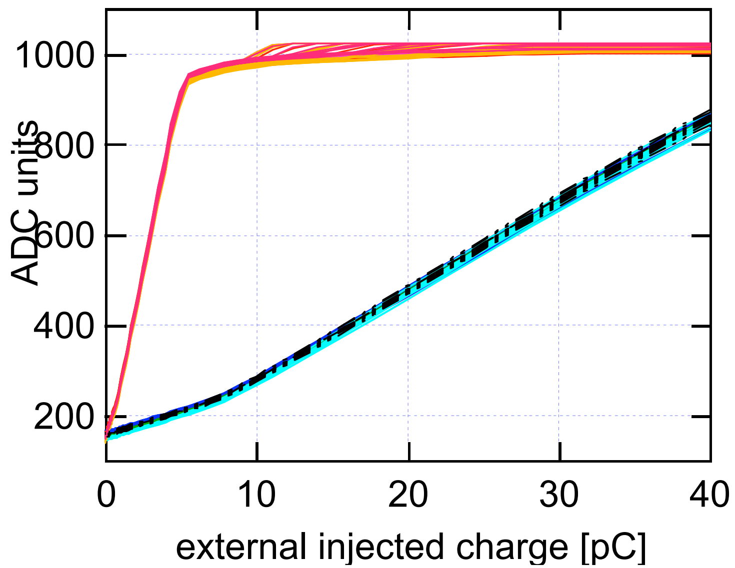
average pedestal value for all 4 chips

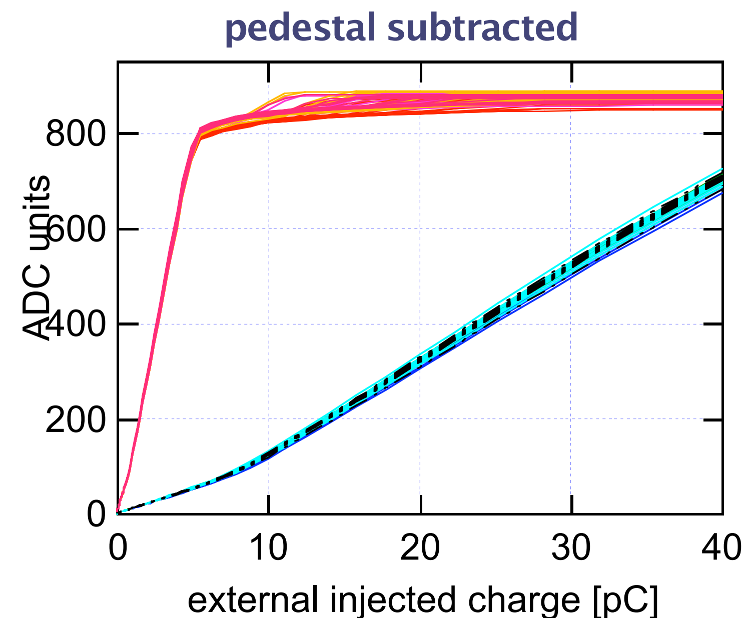
small systematic chip-to-chip differences

1 p.e. ~ 10 ADC units
(for 5x105 photo-sensor gain)

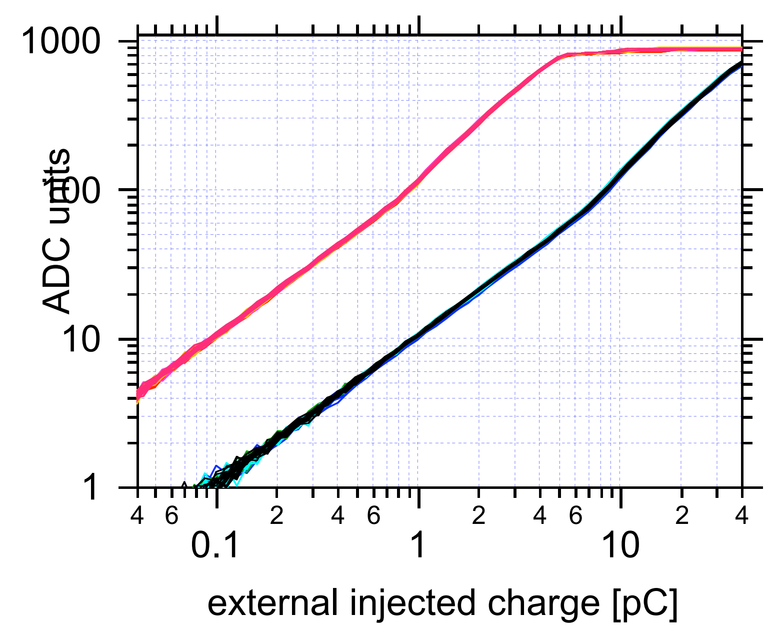
noise ~ 1 ADC unit
small difference in noise between high and low gain channels

TFB linearity

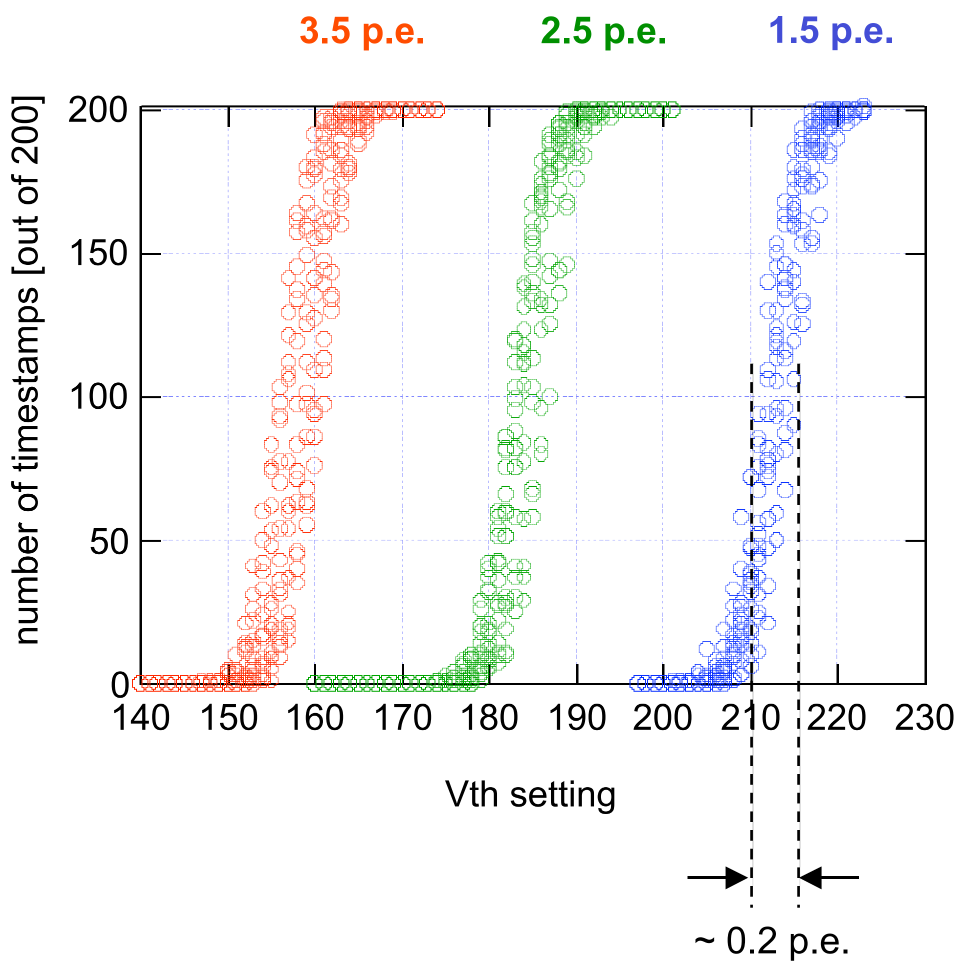




- ➡ 64 high (red) and low (blue) channels (4 TRIP-t's, 16 hi/lo channels per chip
- ➡ Behavior ~ identical to single TRIP-t chip
- ➡ 5% channel spread attributed to gain setting component tolerances
- ➡ Calibration required to correct non-linearities



TFB Discriminator settings



discriminator turn-on curves for all 16 channels from 1 trip-t

measurement procedure:
- inject fixed external charge (200 triggers)
- sweep discriminator thresh. voltage Vth
- count no. of times discriminator fires
  - (no. of timestamps)

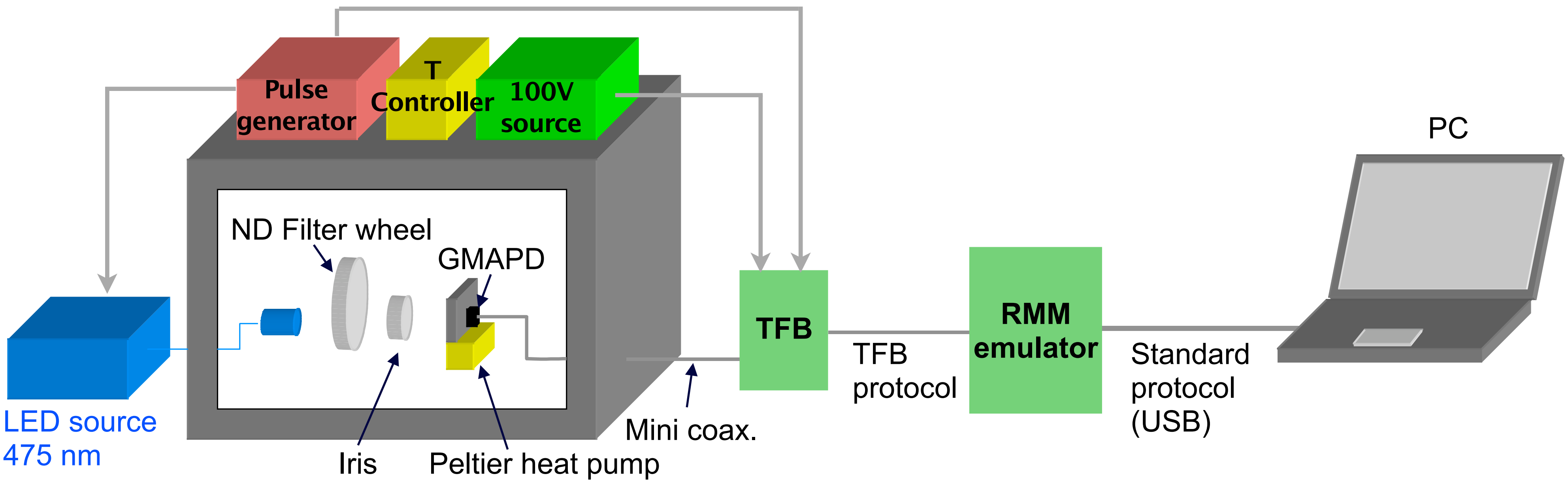
3 separate measurements for 1.5, 2.5 and 3.5 p.e. equivalent external injected charge (assuming $5x10^5$ electrons/p.e.)

channel-to-channel spread better than that previously measured on single chip test board
- possibly attributable to shielded layout of fan-in tracking between input connectors and trip-t I/Ps?

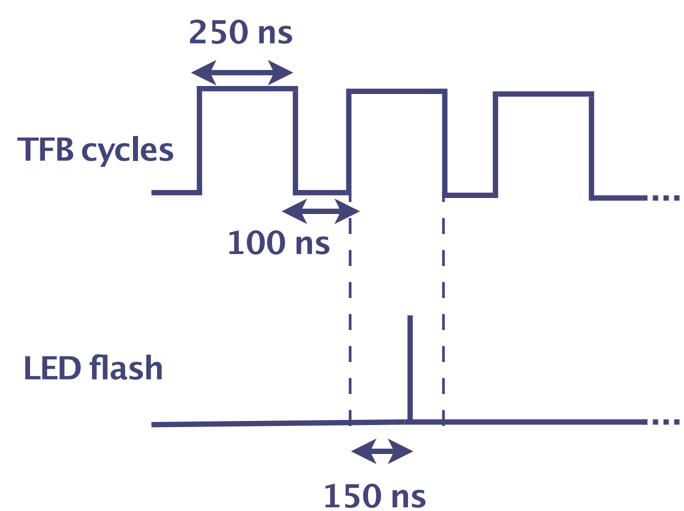
Measurements using GMAPD

- ➡ **Motivation :**
  - Check behavior with T2K GMAPD candidates
  - Identify problems with prototype
  - Start developing large scale sensor QA methods using the TFB
- ➡ **TFB prototypes received beginning of June**
  - Currently under tests
  - TFB firmware well advanced, almost all functionalities being implemented

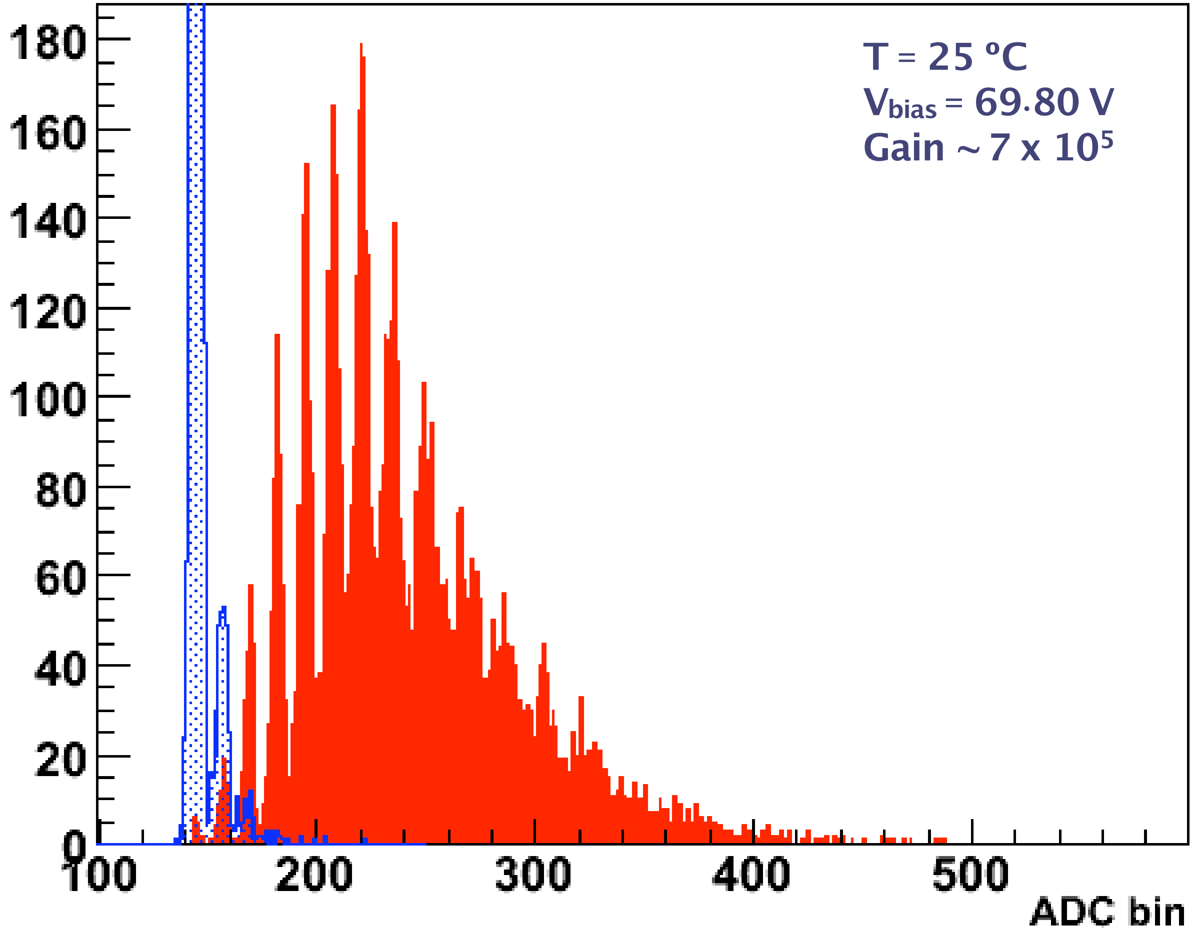
Test setup



- ➡ MPPC 400 and 100 pixels (S1036211XXX-C)
  - Temperature T=25ºC
  - 400 pixels : **G ~ 7x10^5 DCR ~ 400kHz**
  - 100 pixels : **G ~ 1x10^6 DCR ~ 500kHz**
- ➡ NANOLED source, 1 ns pulse width
- ➡ TFB settings
  - **10 integrations window : 250 ns**
  - **reset period : 100 ns**



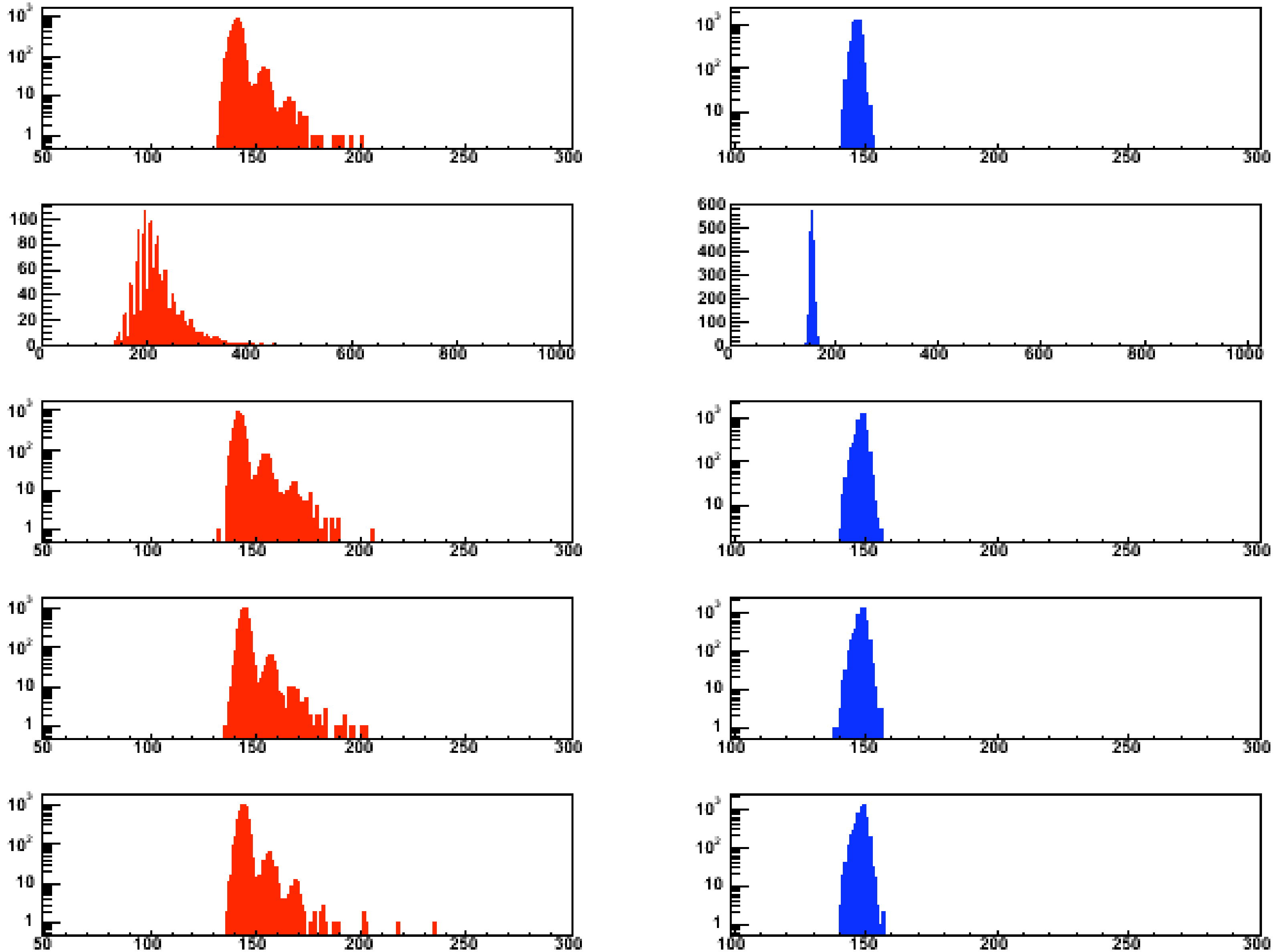
MPPC 400pix ADC spectrum



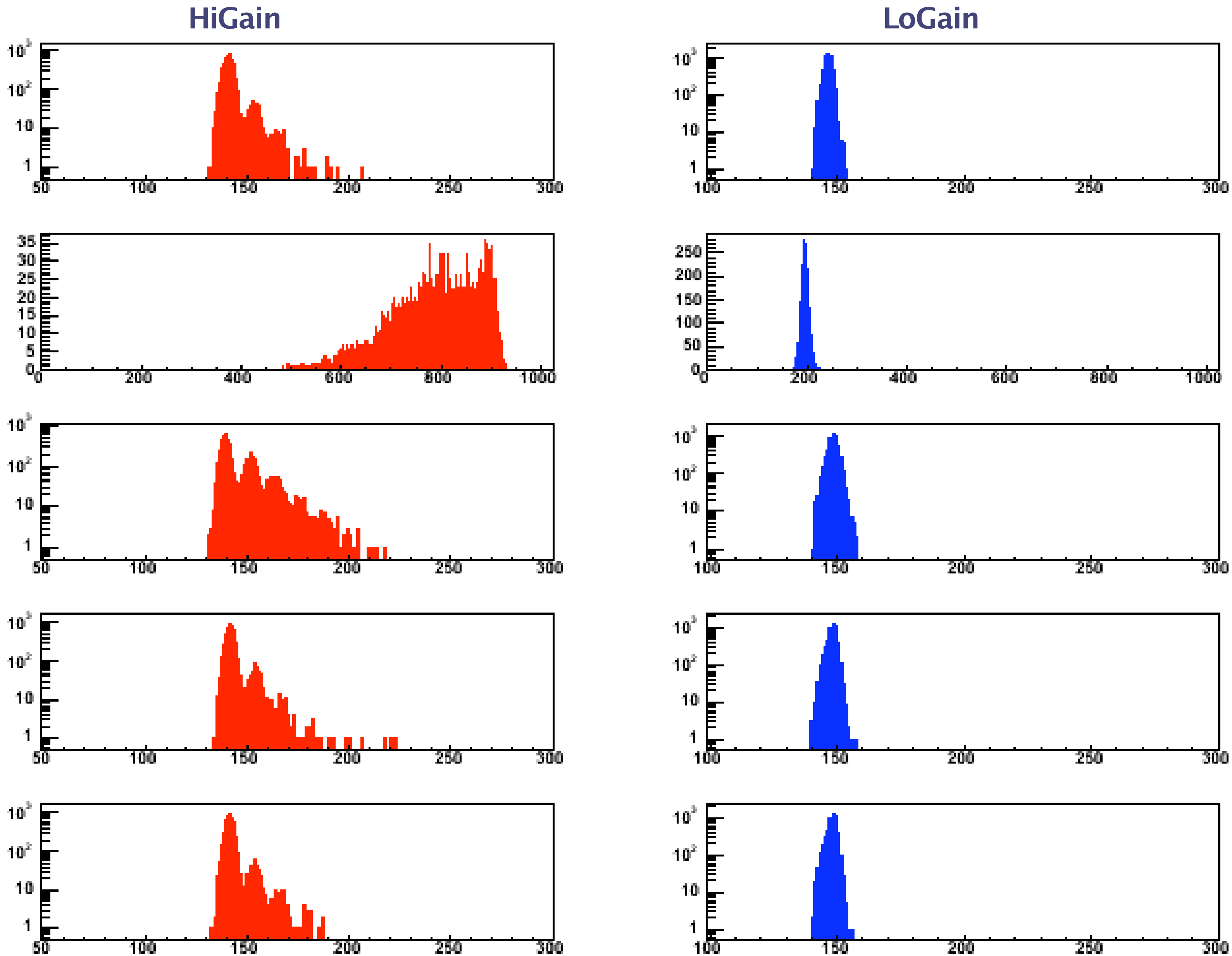
MPPC 400pix low LED ~ 4-5pe

T = 25ºC , V = 69.81V

HiGain | **LoGain**

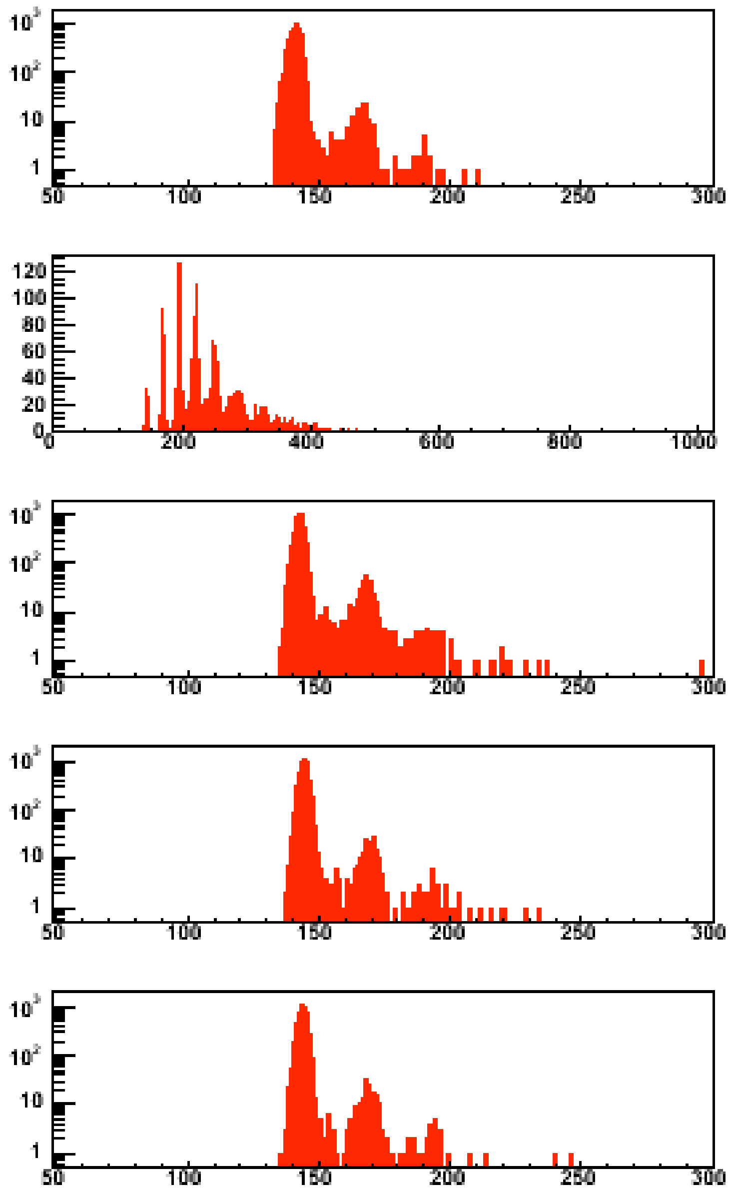


MPPC 400pix medium LED ~ 50pe

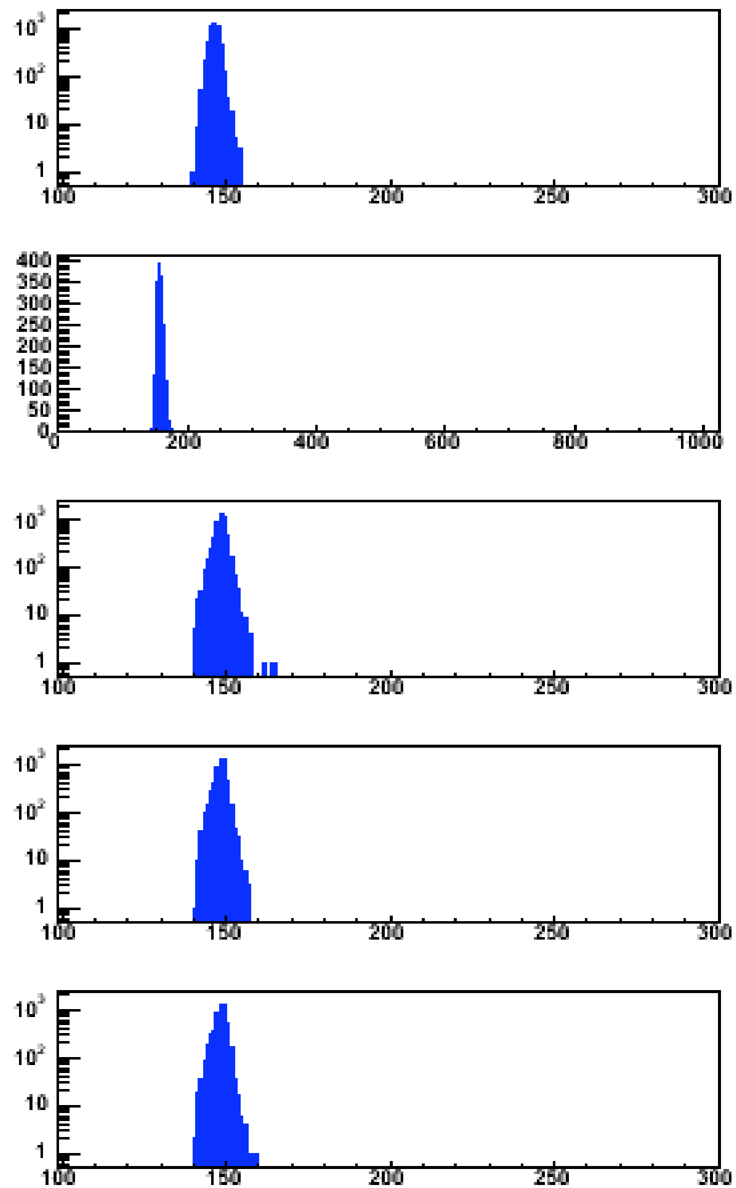


MPPC 100pix low LED ~ 4-5pe

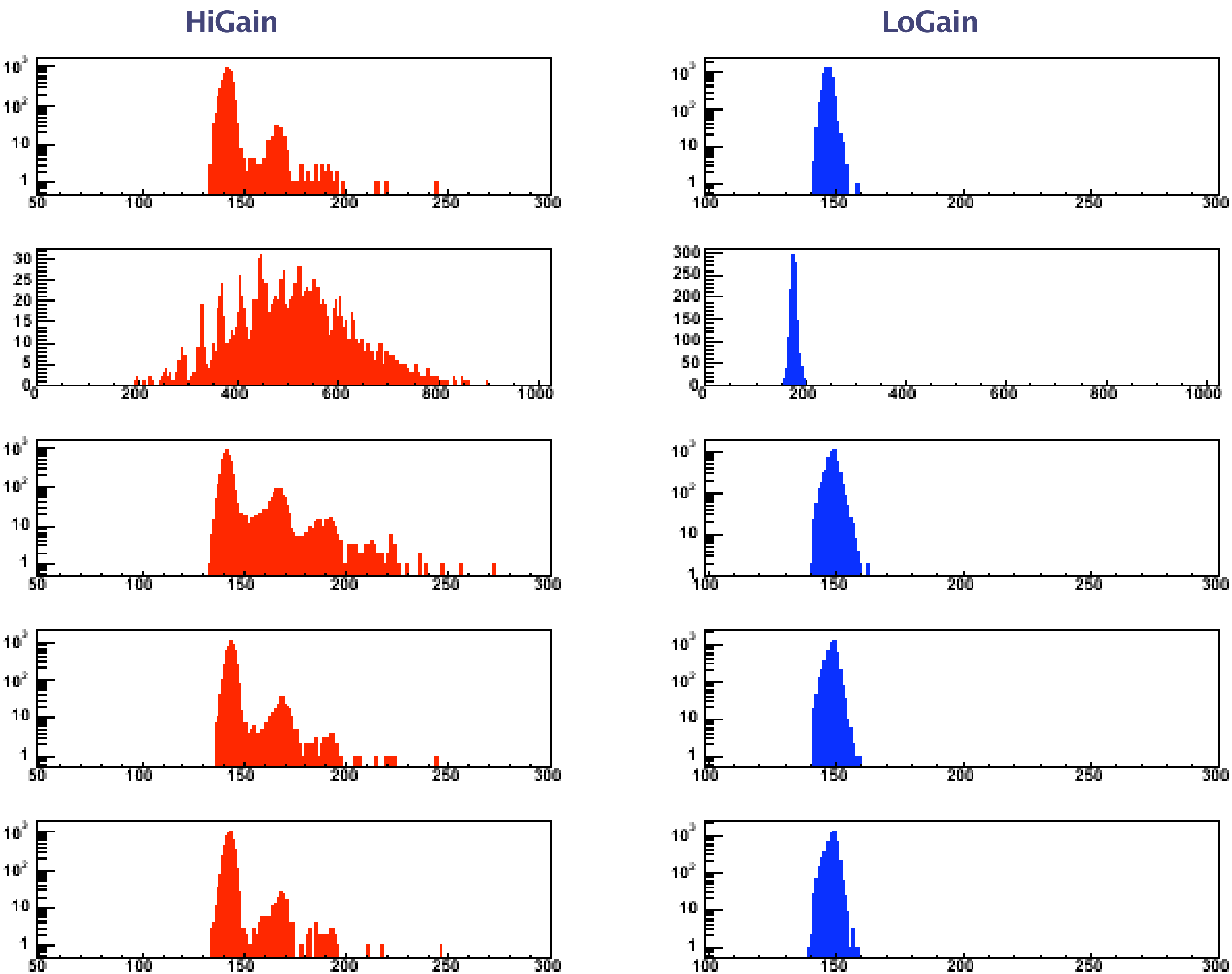
HiGain



LoGain



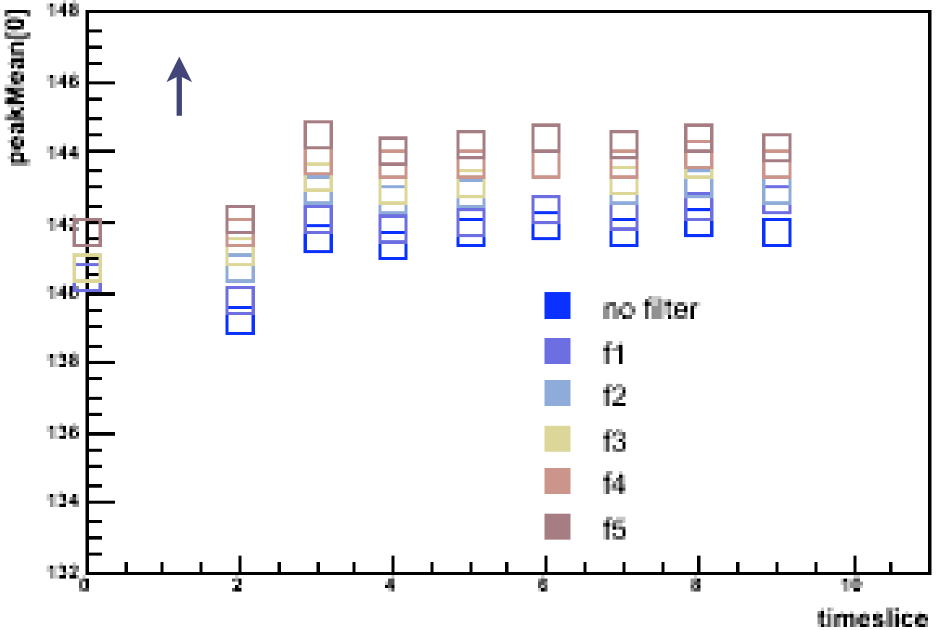
MPPC 100pix high LED ~ 15pe



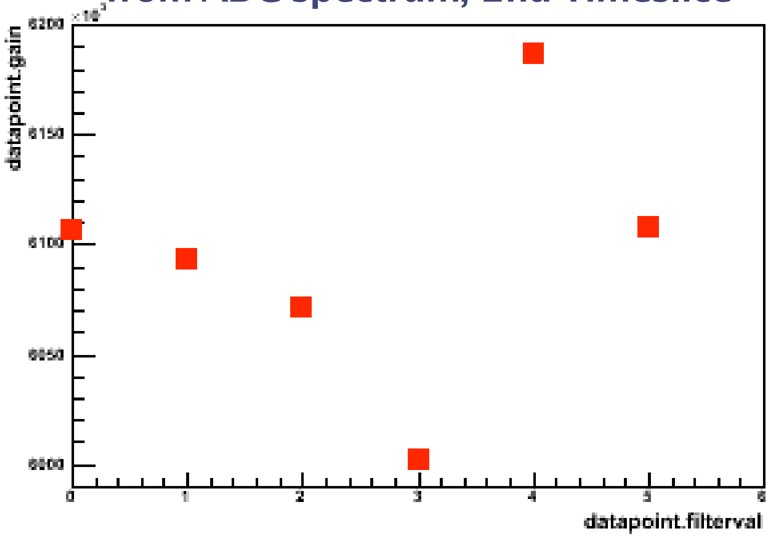
Effect of large signals

- ➡ Large signals induce drop in voltage line :
  - Total charge integrated decreases in following timeslice
  - gain drops by 10% for 100 p.e. signal
  - May affect timestamping
- ➡ HV line recovery time is in the order of few μs
  - Gain drop can be corrected
  - HV line resistor values could be adjusted but signal in next time-slice after very large one will be rare

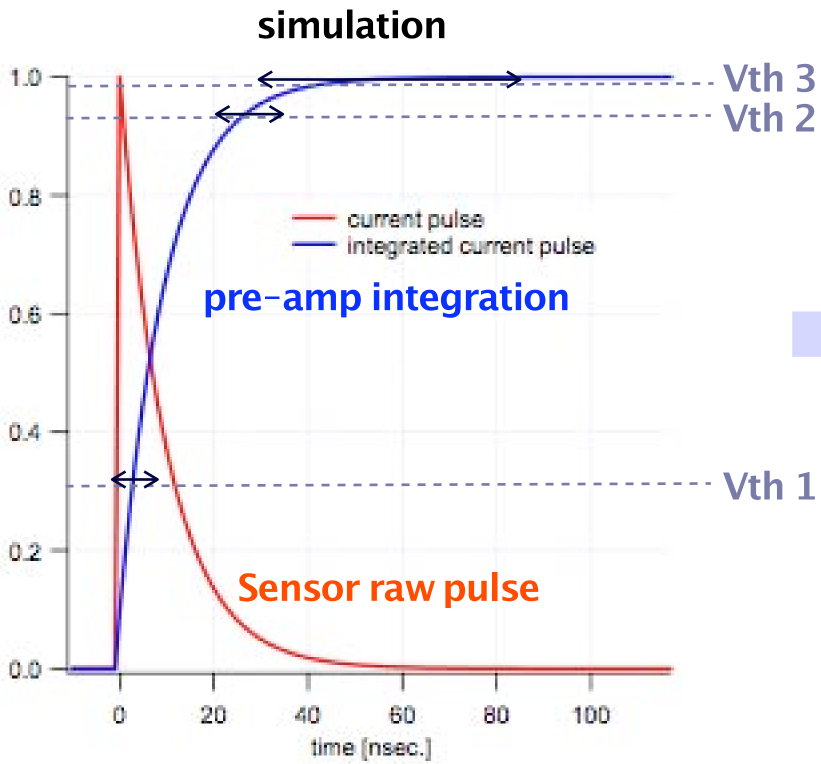
Pedestal mean value HiGain channel 10 timeslice

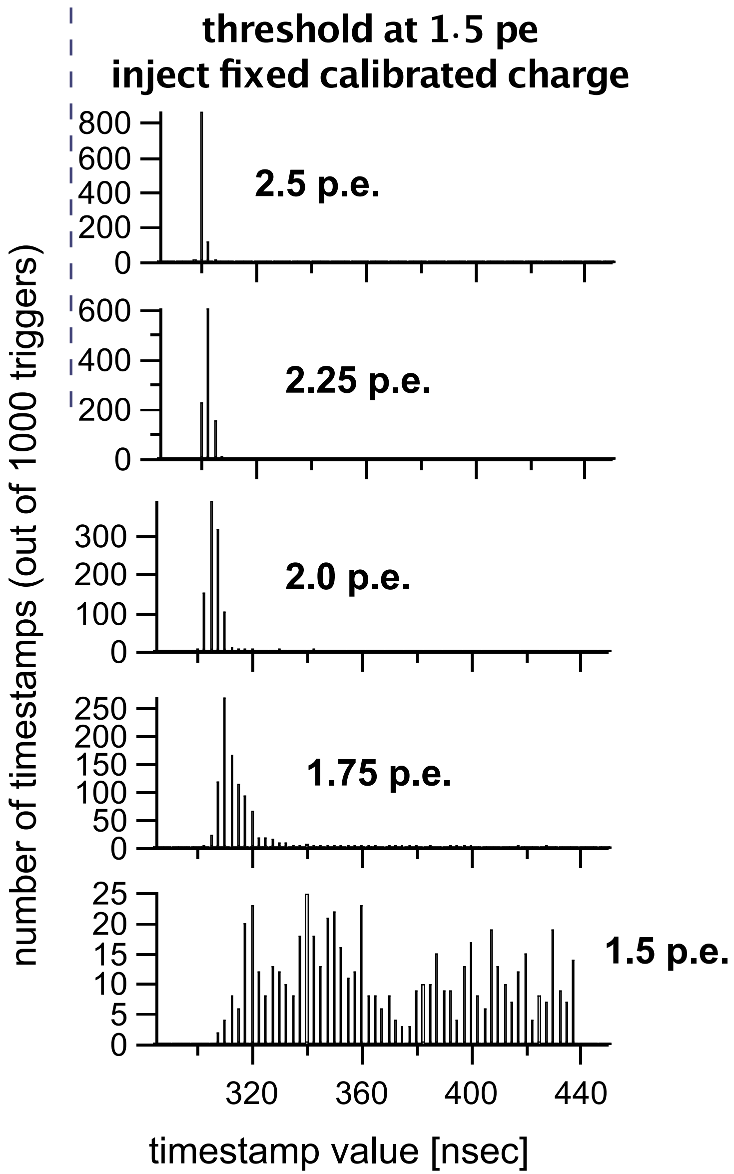


HPK-S1036211050-C gain values from ADC spectrum, 2nd Timeslice



Time Stamping

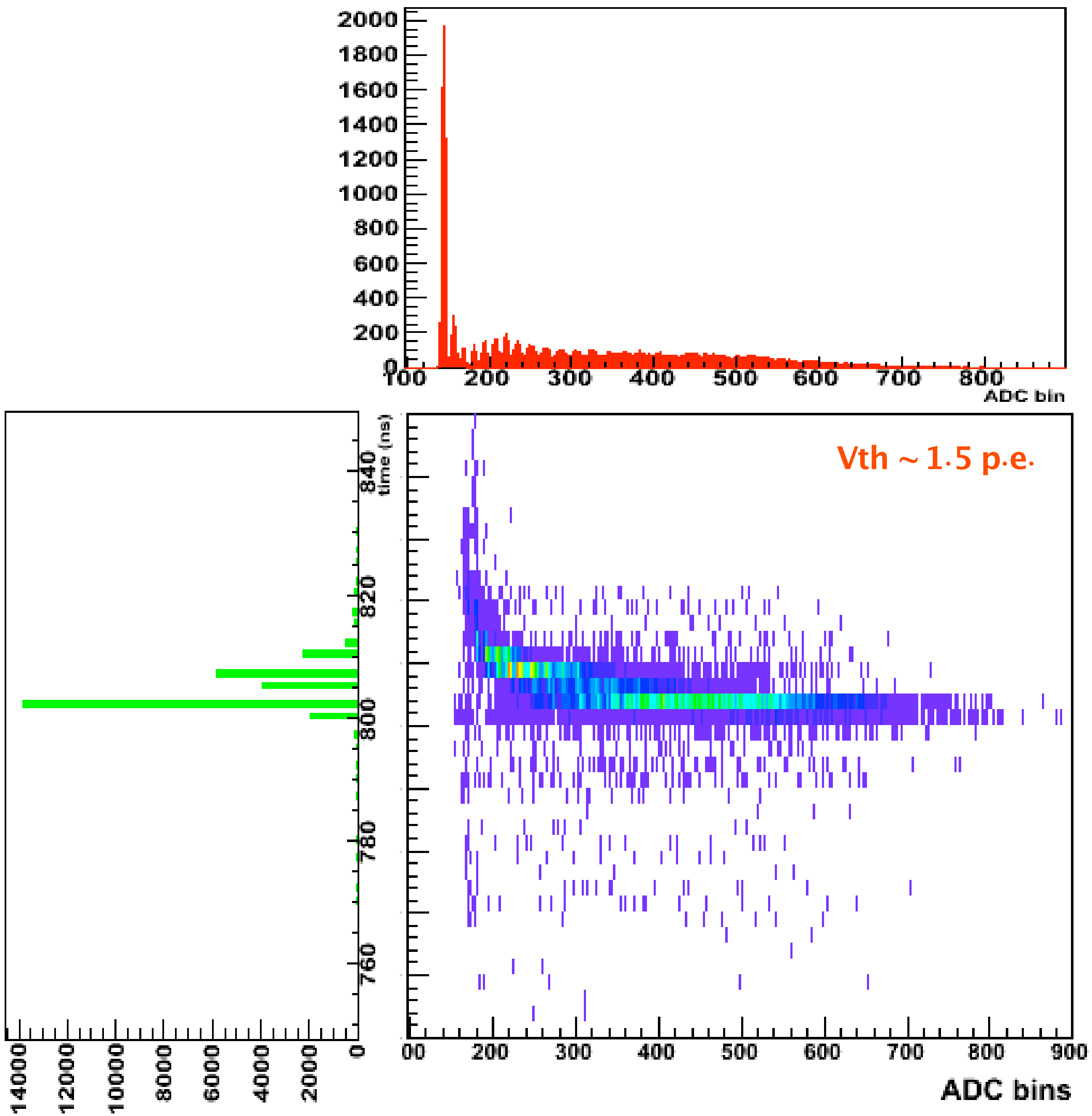




- ➡ Timestamp value is correlated to total charge integrated
- ➡ Discriminator timestamp reliable only when Q ›› Qvth
- ➡ What performance to expect with real GMAPD pulse integration ?

Discriminator Time walk with MPPC I

- HPK-S1036211050-C (400 pixels)
- Threshold Vth = 1.5 p.e.
- Acquired 10000 triggers for 4 different LED intensity (0 to ~40 p.e.)
  - Readout ADC data and timestamp
  - Cut on 2nd timeslice
  - Correlation shows sum of all 4 measurements for $N_{timestamp} > 0$

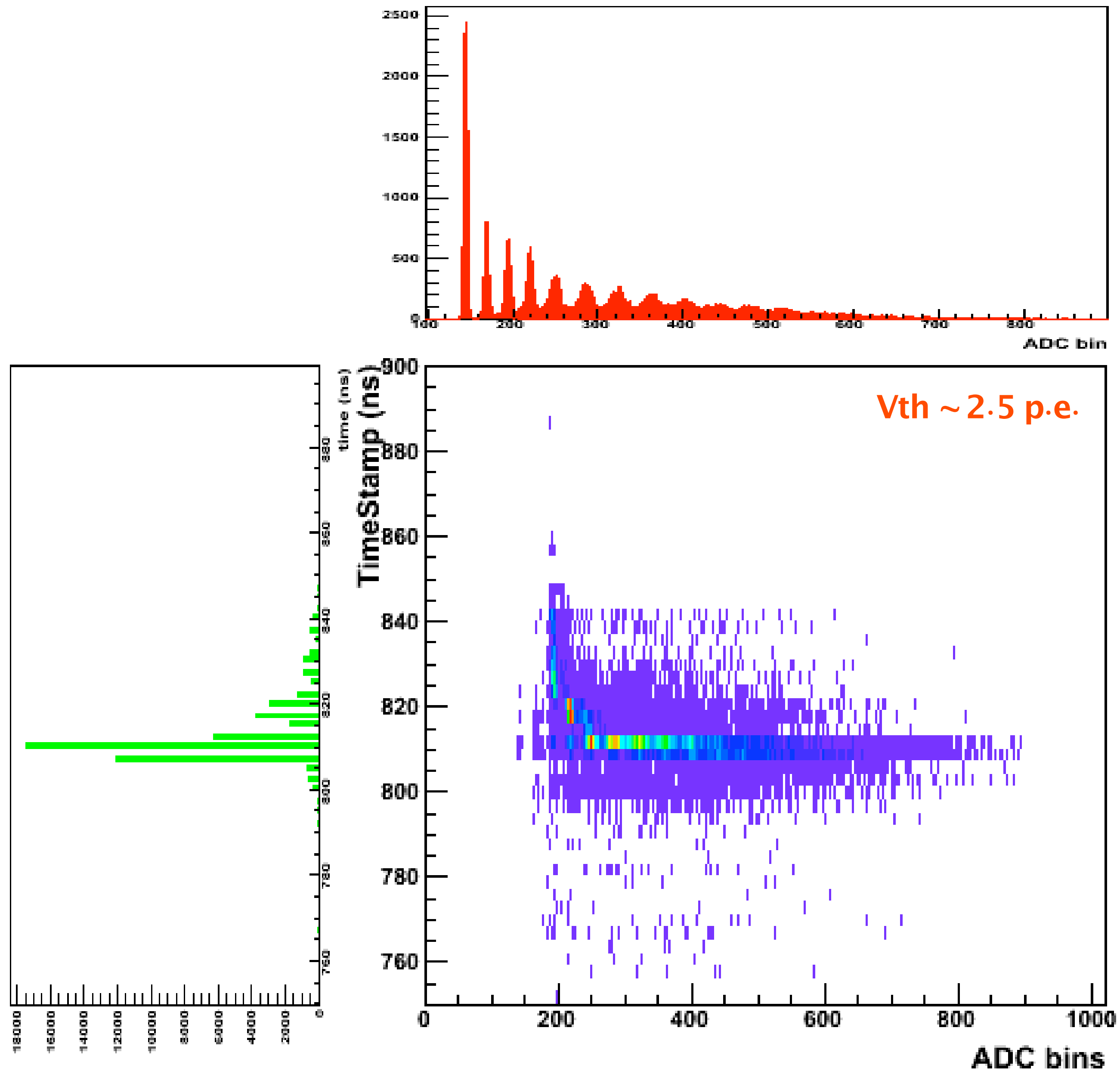


- **Time resolution ~ 1 ns for signal > 10 p.e.**
- **Very promising timing performance with GMAPD response**

Discriminator Time walk with MPPC II

- HPK-S1036211100-C (100 pixels)
- Threshold Vth = 3.5 p.e.
- Same measurement as before but Vth set according to increase in gain

- **Good time resolution but larger spread of signal due to long pixel decay time (~100 ns) and possibly afterpulse**



Time Resolution

- ➡ Preliminary results suggests that a time resolution of 1 ns or better is achievable
  - study in progress
- ➡ Ultimately time performance will depend on light yield and threshold setting for each sub-system
  - Need full detection chain test with cosmic muons
  - Optimum threshold setting depends on dark count rate and light yield

Voltage scans

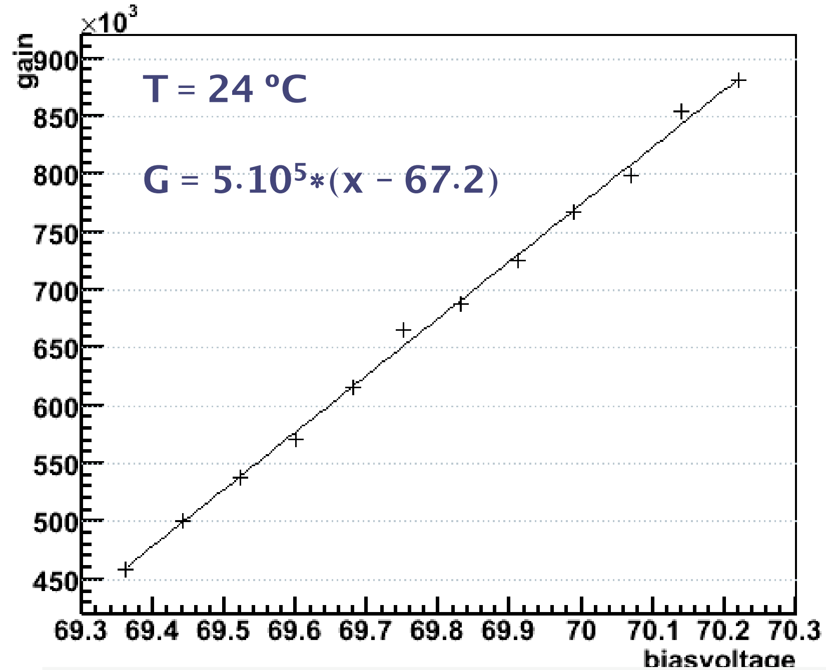
➡ Motivation :

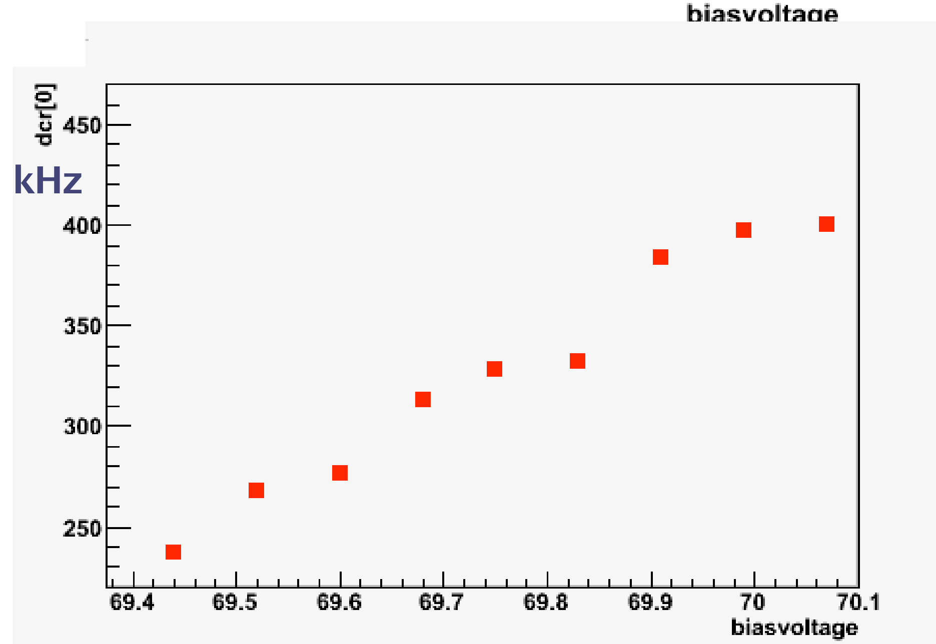
- Sensor parameters measurements (QA) using ADC spectrum
  - gain
  - dark count rate,
  - pixel crosstalk, afterpulse
- T2K run : inter-calibration and correction for gain variations

➡ TFB has 10bit DAC : +5V, 20 mV voltage resolution

Voltage scan

- ➡ 80 mV steps, pedestal run
  - 4x more points possible with DAC
- ➡ Gain extracted using peak to peak method
- ➡ Dark count rate estimation using ratio : 0.5p.e./Nevent
- ➡ Study voltage scans in more details to ensure good accuracy of voltage control



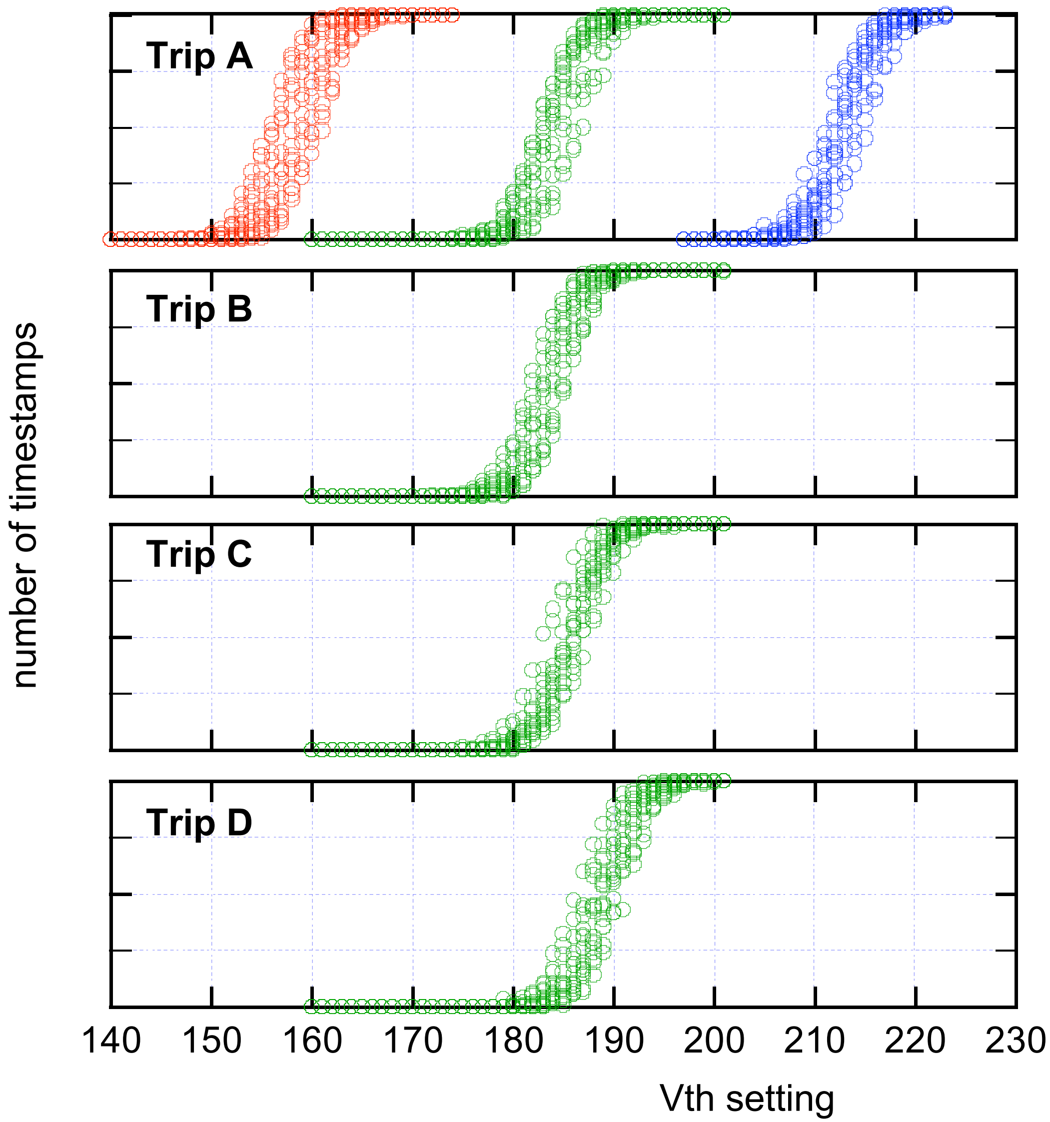


Summary and schedule

- ➡ Early study of the TFB prototype shows very good performances with MPPC devices
  - good signal charge and time resolution
- ➡ TFB functionalities under tests
  - Voltage scan using HV trim works
- ➡ TFB final modifications before end 2007
- ➡ Production of TFB and Back end board Apr **2008**
- ➡ GMAPD delivery and tests planned in **early 2008** for most nd280 sub-systems
- ➡ INGRID commissioning **Jan 2009**
- ➡ T2K starts **Apr 2009**
- ➡ nd280 commissioning **Oct 2009**
- ➡ nd280 data taking **Nov 2009**

Chip to Chip variations

➡ Discriminator threshold



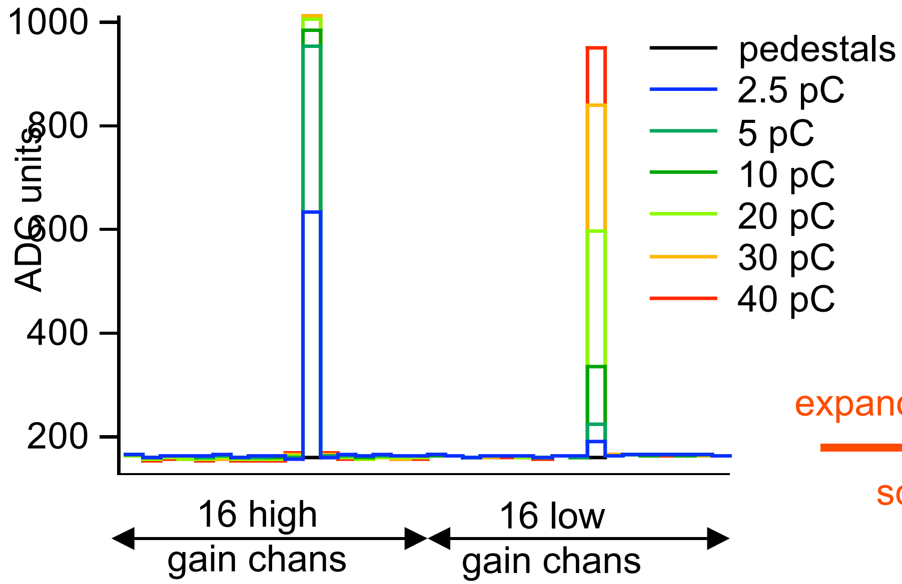
repeat previous measurement for other 3 trip-t's (2.5 p.e. Qin only)

spread ~ same for all 4 chips

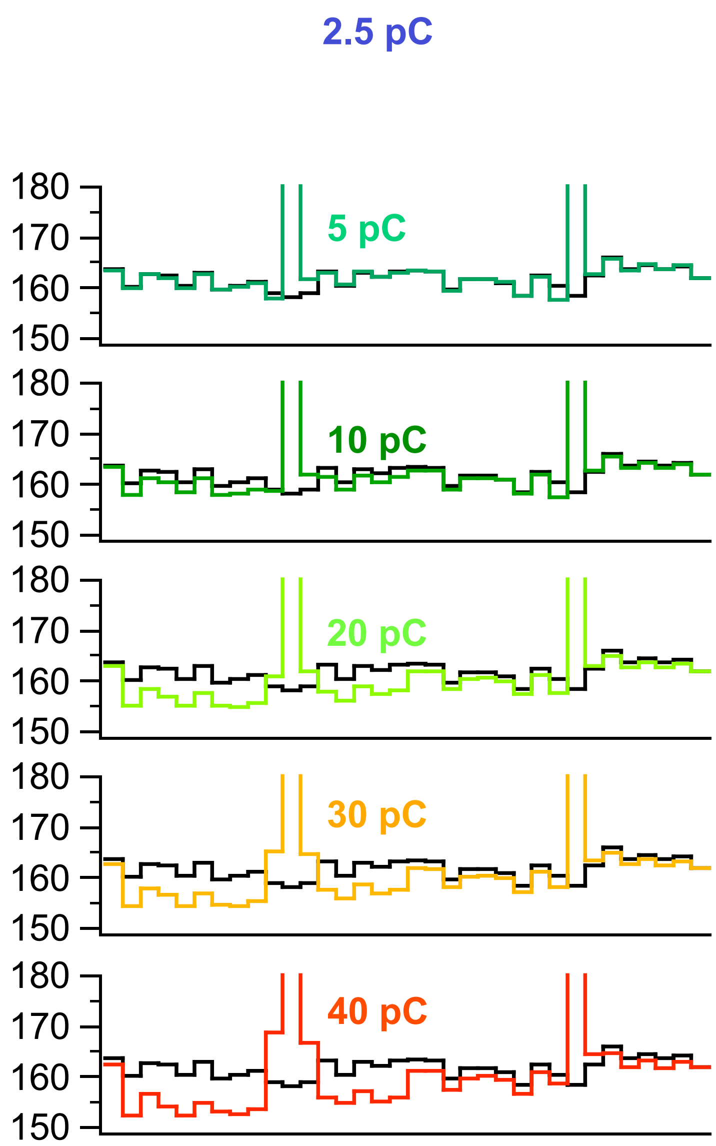
small systematic chip-chip offset, but can program Vth individually for each chip anyway

TFB channel crosstalk

data from one trip-t, injecting external charge on one channel



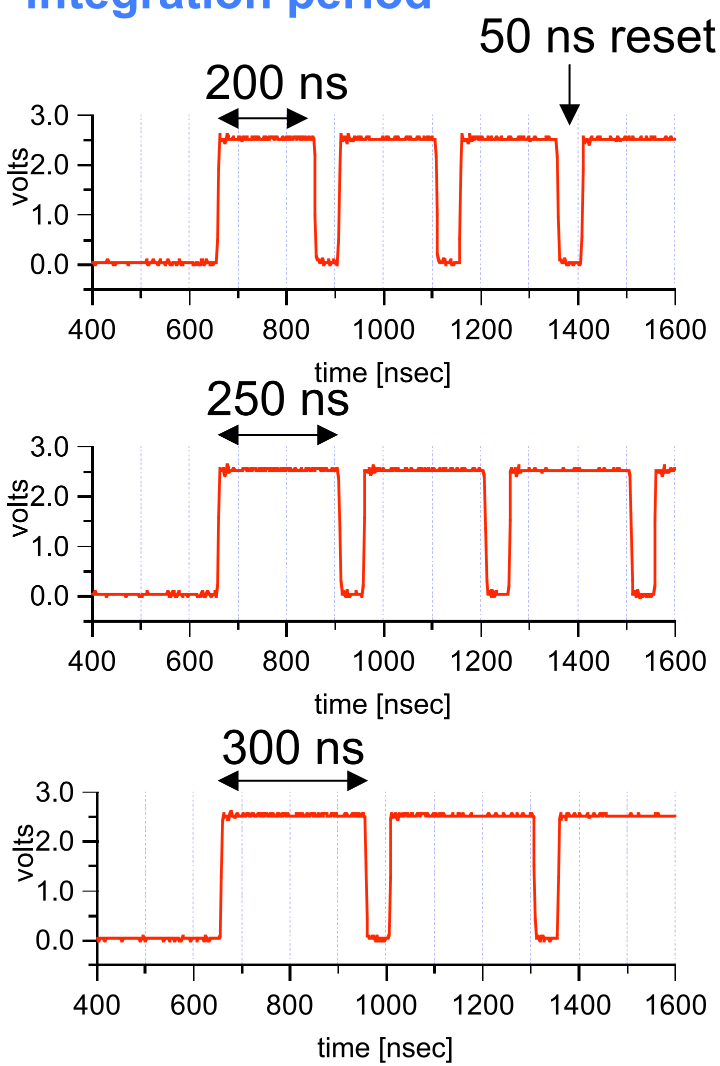
expand vertical scale



for 500 p.e. signal (40 pC) get ~ 1 p.e. signal in neighbouring hign gain channels, and ~1 p.e. depression of pedestals in other high gain channels (~ 0.2 % effects)

Programmable Integration/Reset

integration period



preamp integration/reset time
independently programmable

reset period