Update analysis of TPC detector prototype using UV laser tracks

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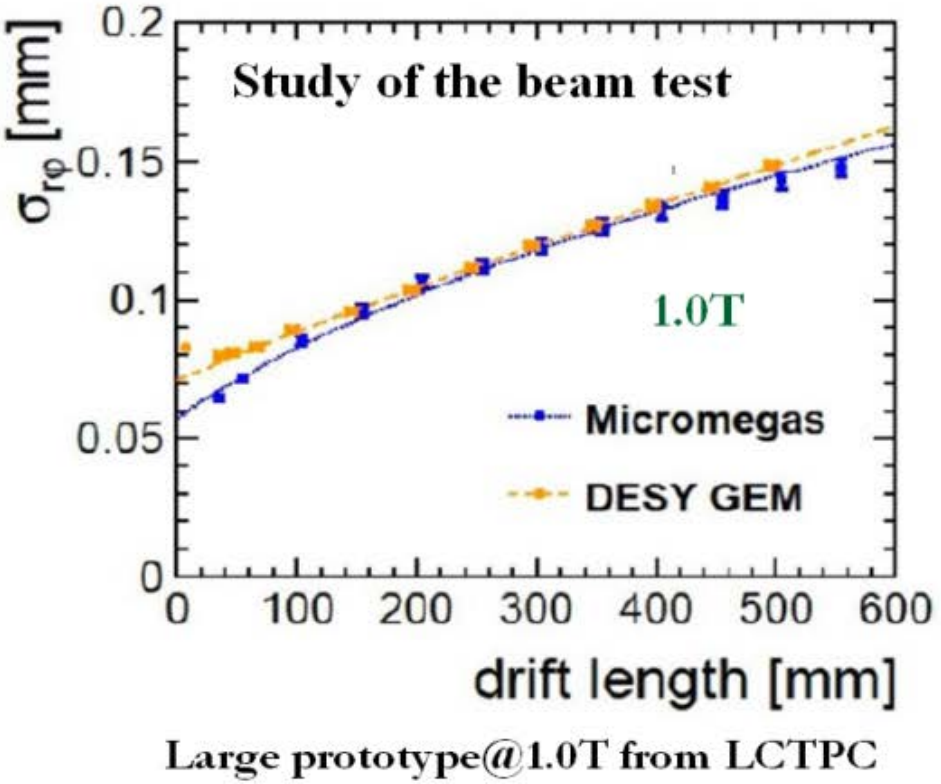
Overview

1. TPC detector with UV laser
2. dE/dx resolution
3. New electronic testing

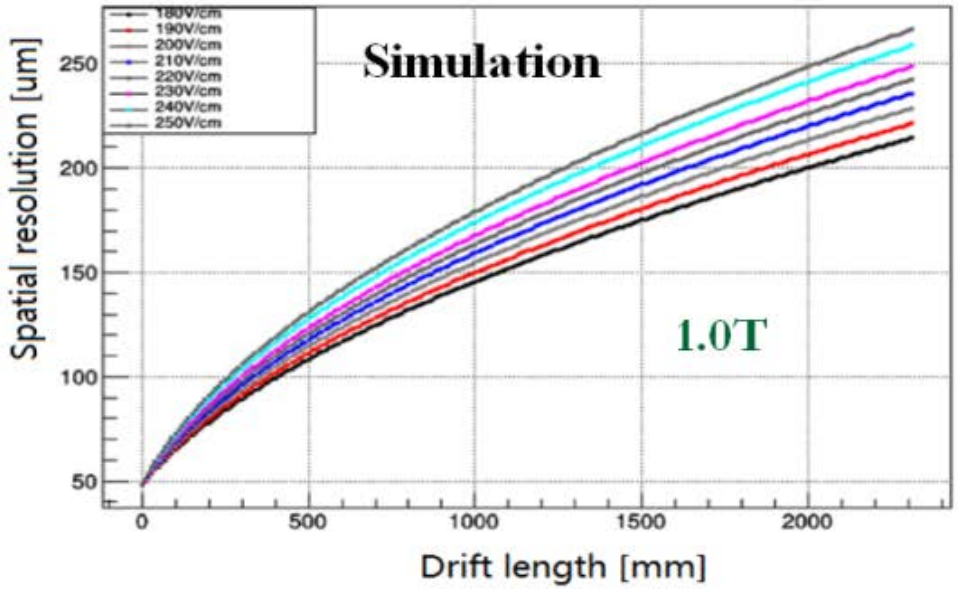
Motivation- spatial resolution

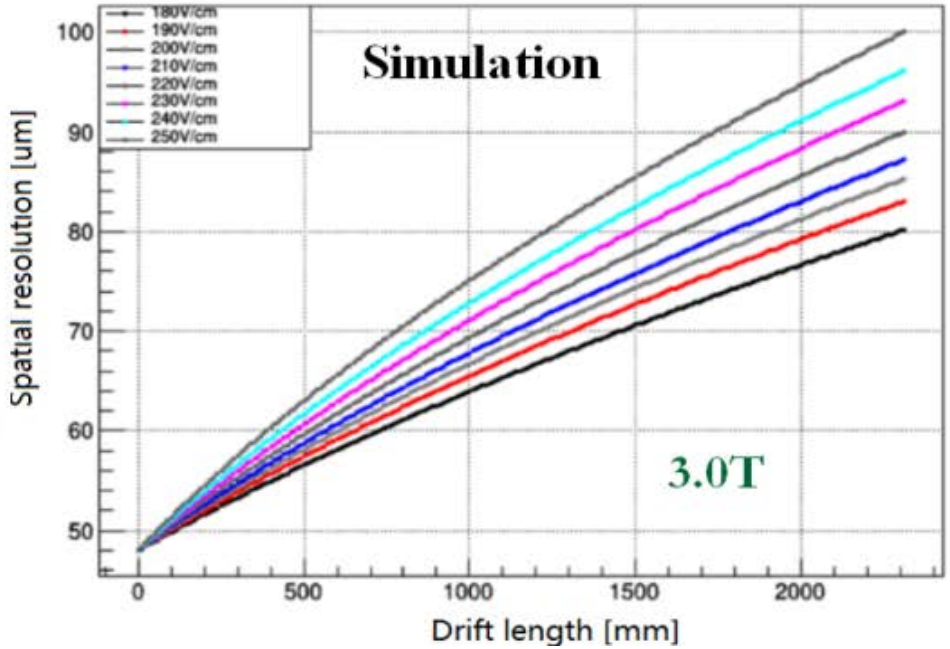
$$\frac{\sigma_{p_\perp}}{p_\perp} = \sqrt{\left(\frac{\alpha'\sigma_x}{BL^2}\right)^2 \left(\frac{720}{N+4}\right) p_\perp^2 + \left(\frac{\alpha' C}{BL}\right)^2 \frac{10}{7}\left(\frac{X}{X_0}\right)}$$

measurements — multiple scattering



Large prototype@1.0T from LCTPC





Motivation- Particle identification

$$\sigma_{dE/dx} = \sigma_0 N_{hits}^{-k}$$

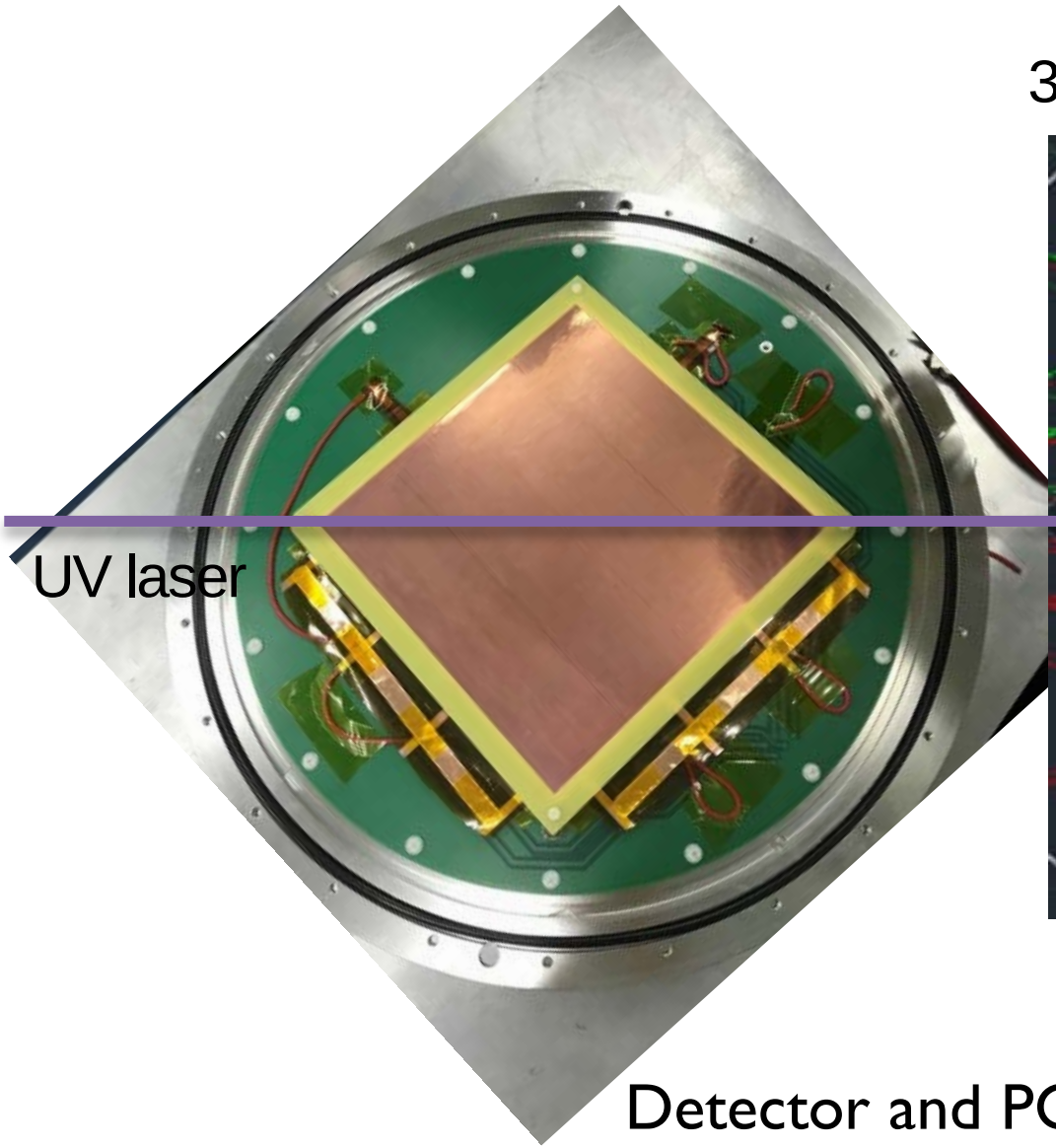
Experiment	Readout	Points	Sample	$p(GeV/c)$	$(\sigma_I/I)_{MC}$	$(\sigma_I/I)_{exp}$
	Pad (mm)					
PEP-4 TPC	4	183	e	14.5	2.6%	3.5%
TOPAZ TPC	4	175	π	0.4-0.6	3.8%	4.5%
DELPHI TPC	4	192	π	0.4-0.6	5.4%	6.2%
ALEPH TPC	4	344	e	45.6	3.0%	4.4%
STAR TPC	12, 20	13,32	π	0.4-0.6	5.3%	6.8%
ALICE TPC	7.5, 10, 15	63,64,32	π	6.0	3.3%	5.0%
TPC for CEPC	1mm×6mm	220	K	5.0	3.1%	
	Pixel(μm)					
GridPix TPC for ILD	55×55	9500	e	2.5	/	4.1%

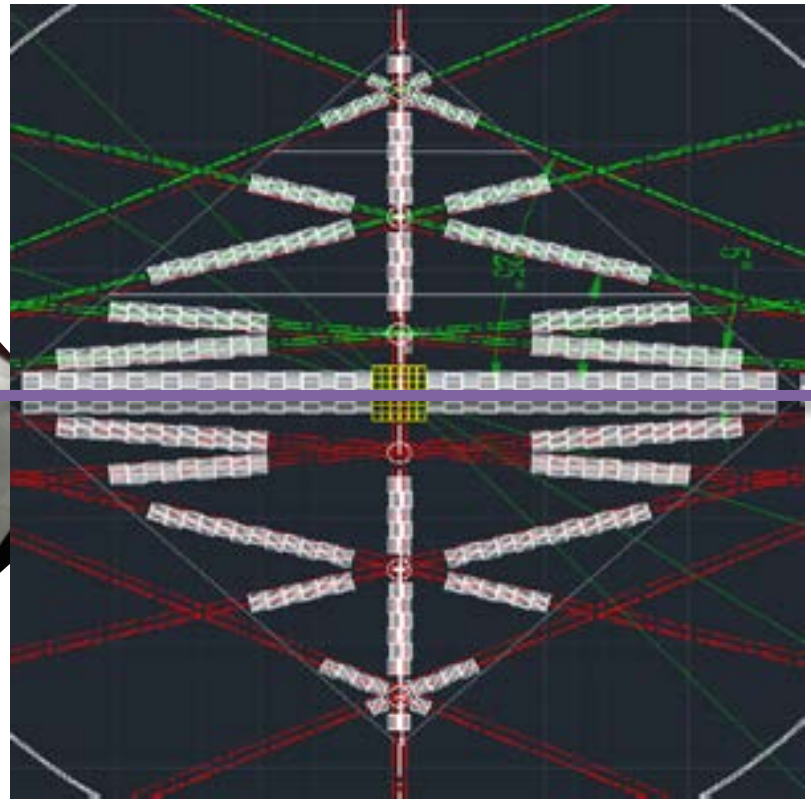
NO magnetic field
NO high energy particle testing beam

UV lasers (5 years R&D)

TPC detector with UV laser

Pad size: 1mm × 6mm
38 hit points per track by UV laser





Detector and PCB readout board

TPC detector with UV laser

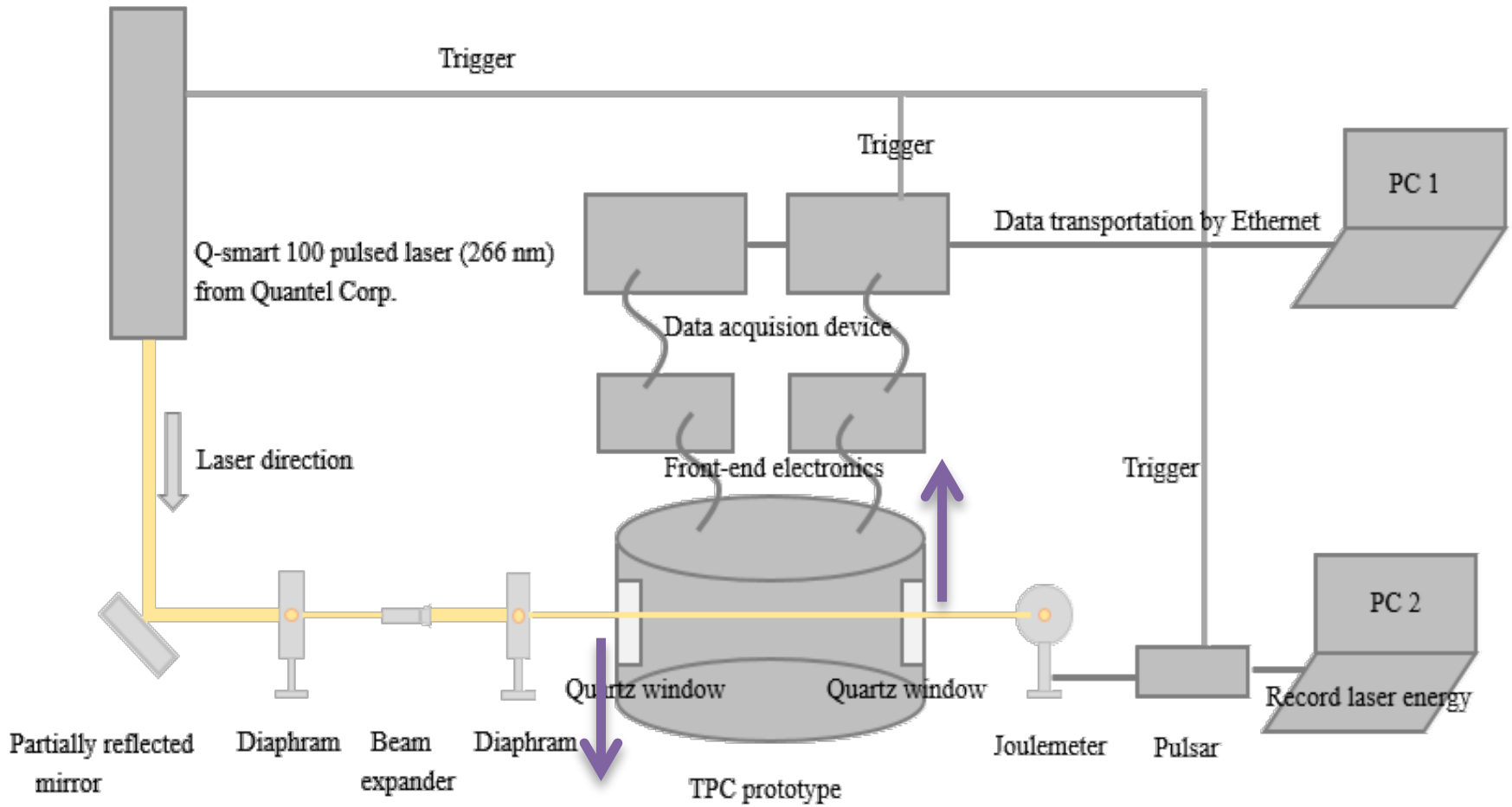
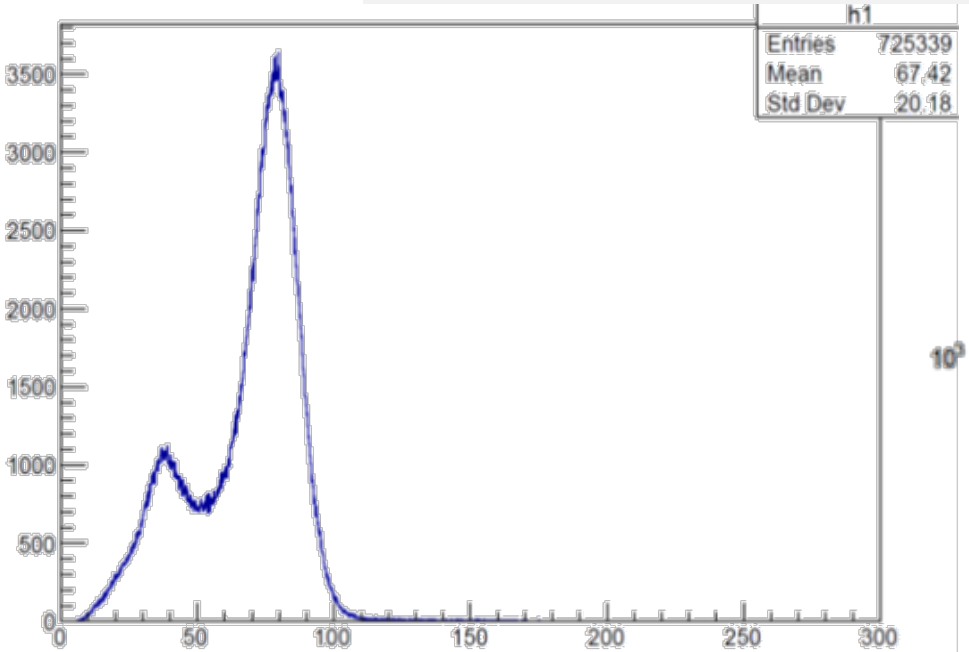
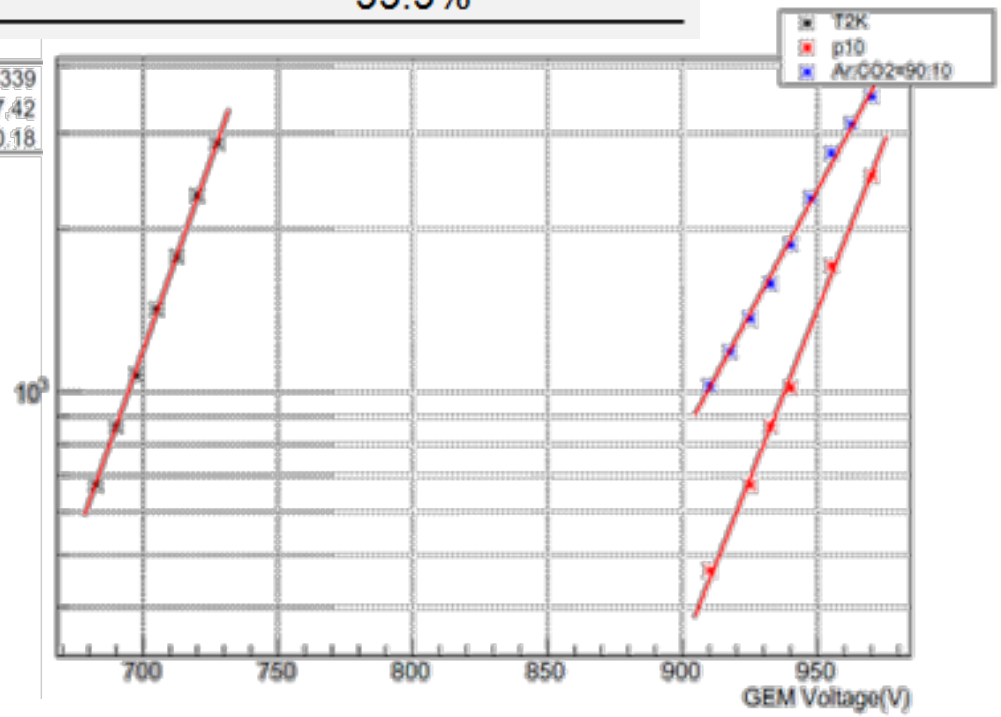


Diagram of TPC detector study

^{55}Fe study

Gas	Purity
Ar	99.999%
CO2	99.999%
CH4	99.999%
CF4	99.999%
Isobutane (iC4H10)	99.9%

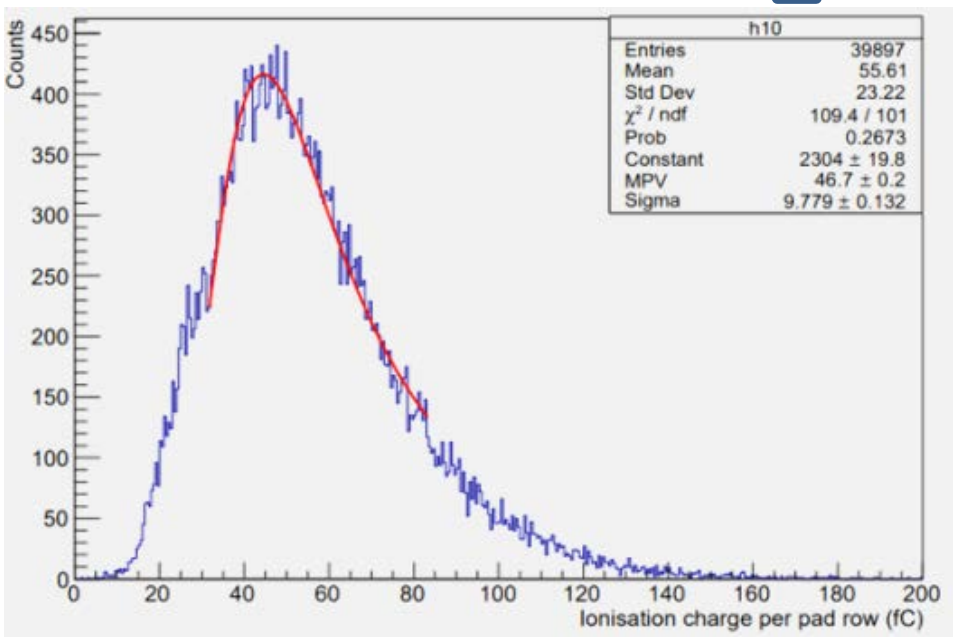


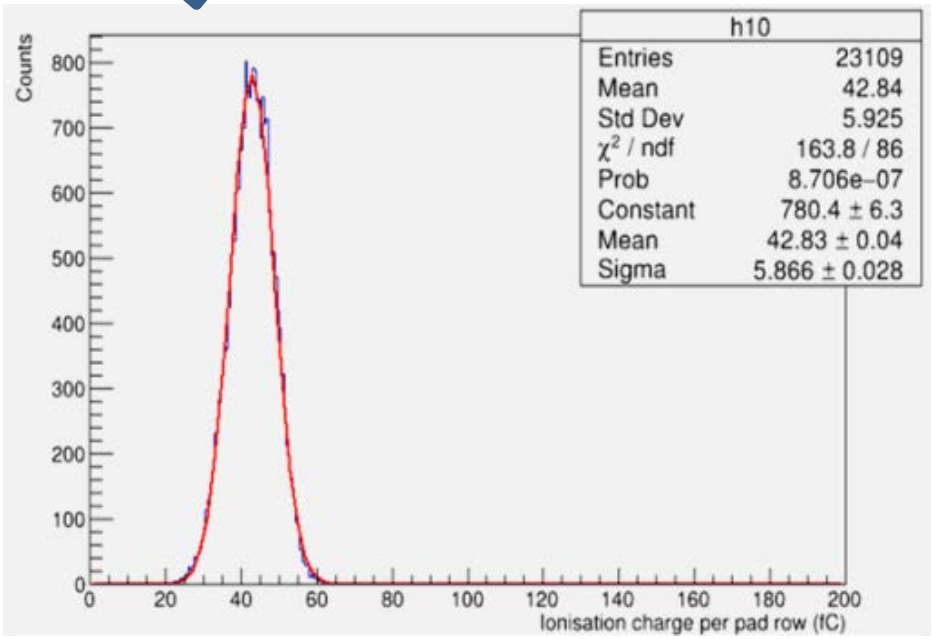


Energy spectrum and gain at T2K/P10/Ar:CO2

UV laser spectrum - Truncated method

Energy cutting and correction by the events

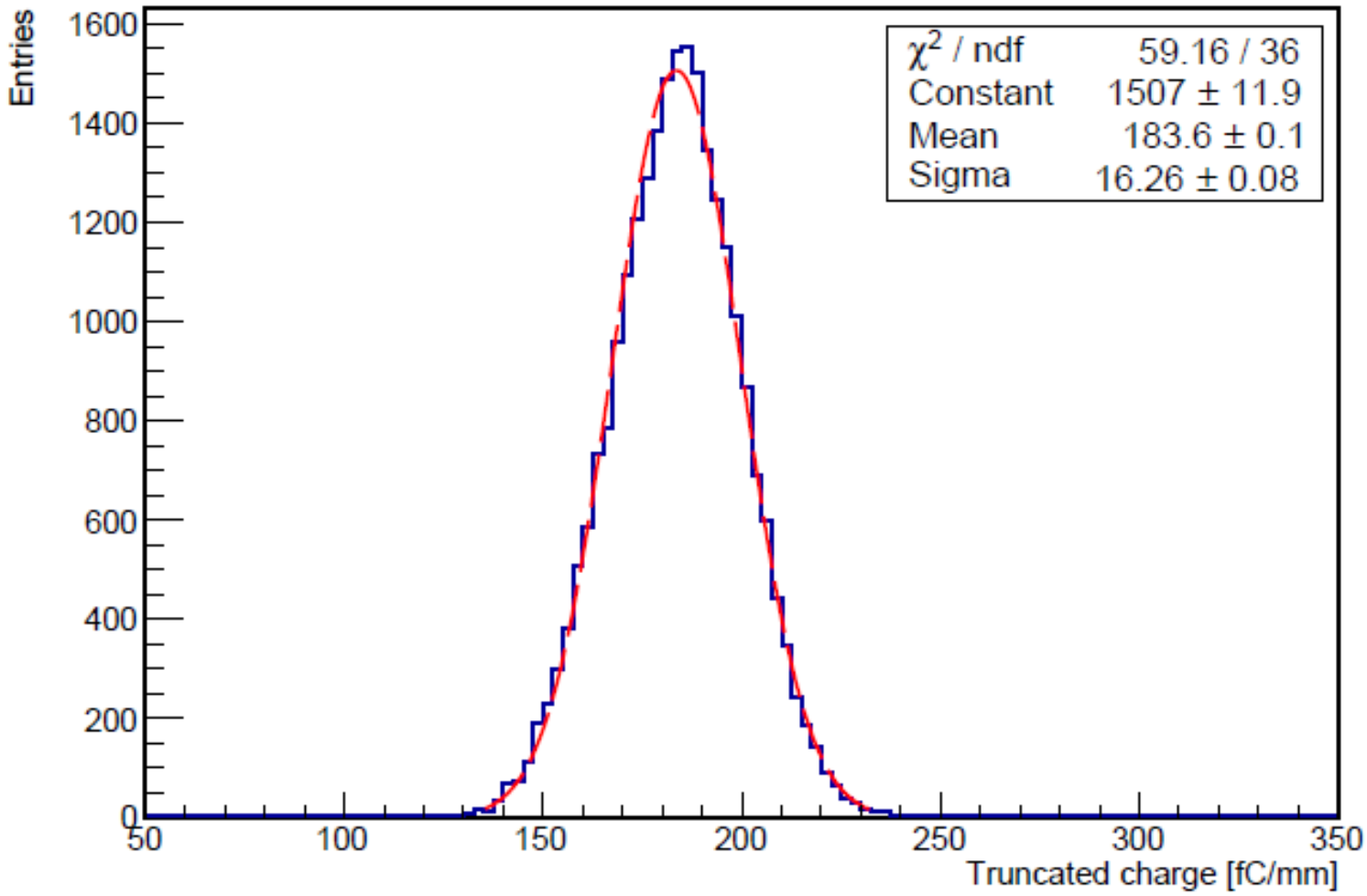




Energy spectrum of UV

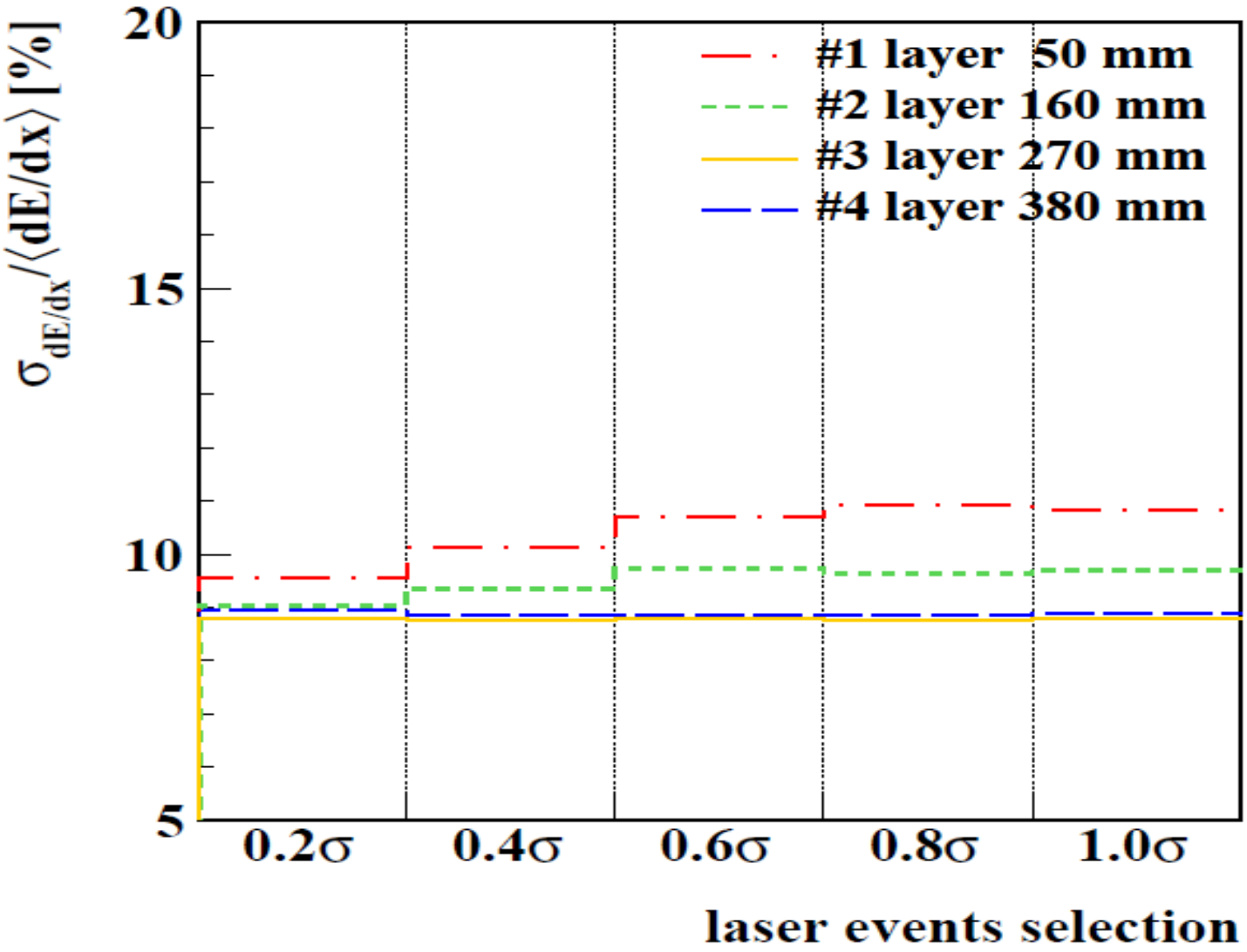
dE/dx resolution – 38 hit points

$$\sigma_{dE/dx} = (8.9 \pm 0.4)\,\% \textbf{(38hits)}$$



laser events using energy cutting and correction

dE /dx resolution – along drift length

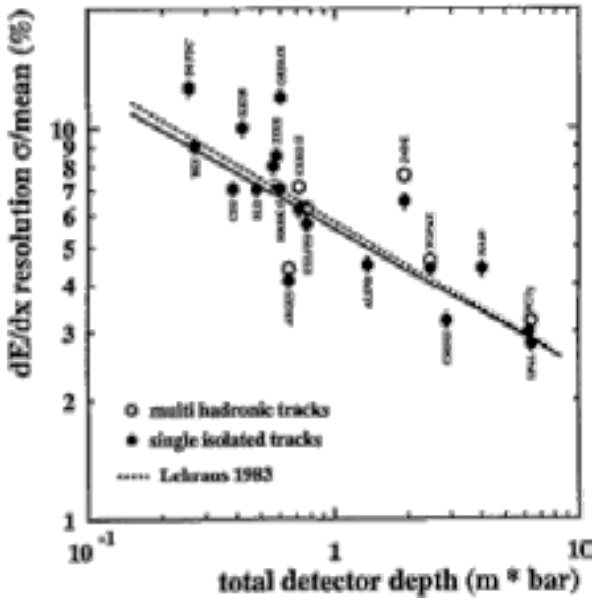


dE/dx resolution along the drift length of TPC prototype

dE /dx resolution - pseudo-tracks using full size

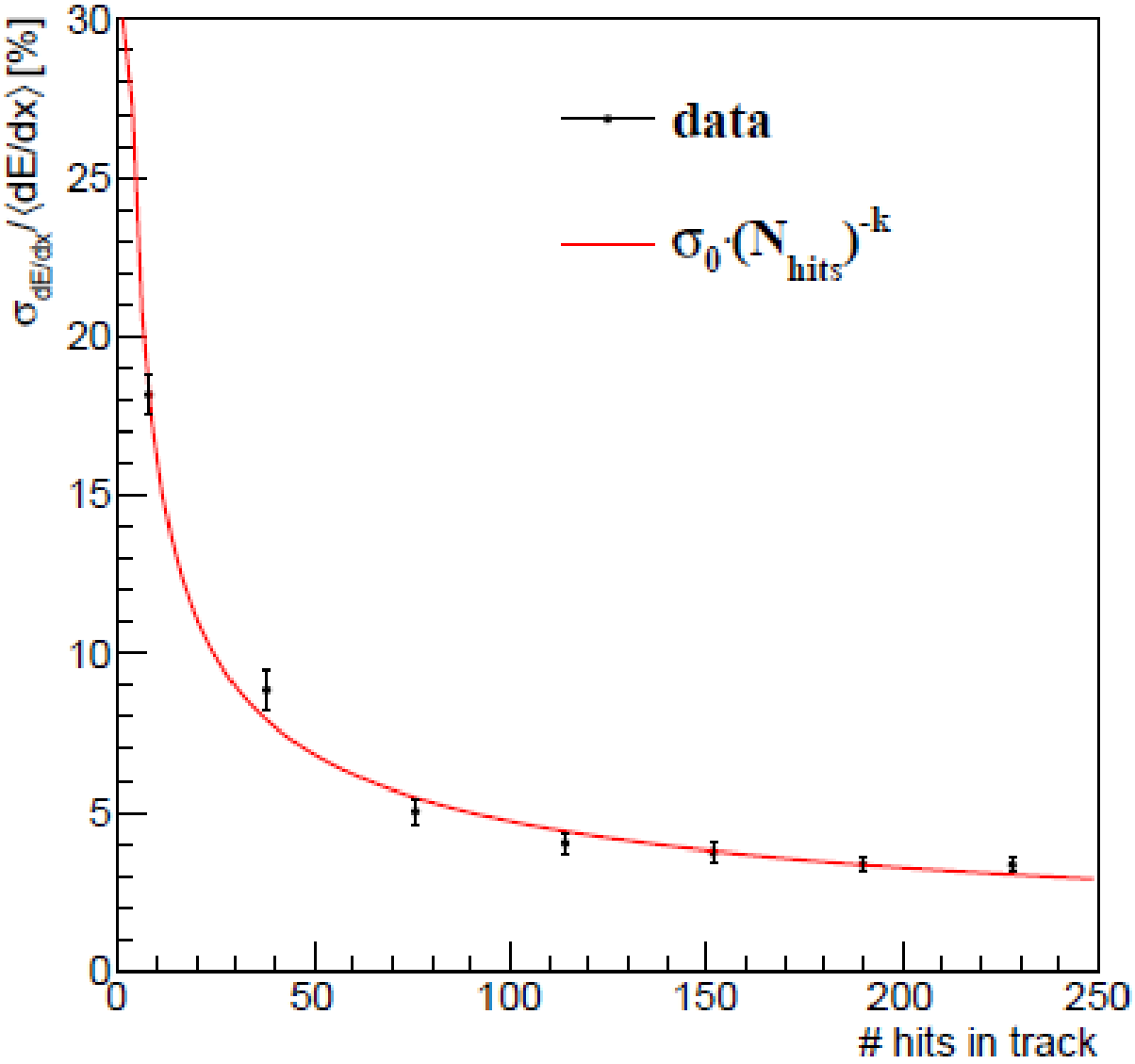
$$\frac{\langle dE/dx \rangle}{\sigma(dE/dx)}$$

220 points per track
Full size of CEPC TPC concept



Hauschild's formula	$\frac{\sigma(dE/dx)}{dE/dx} = 5.5 \times L^{-0.36}\ (\%)$
Walenta's formula	$\frac{\sigma(dE/dx)}{dE/dx} = 5.57 \cdot L^{-0.30}\ (\%)$

dE /dx resolution - pseudo-tracks of the different hit points



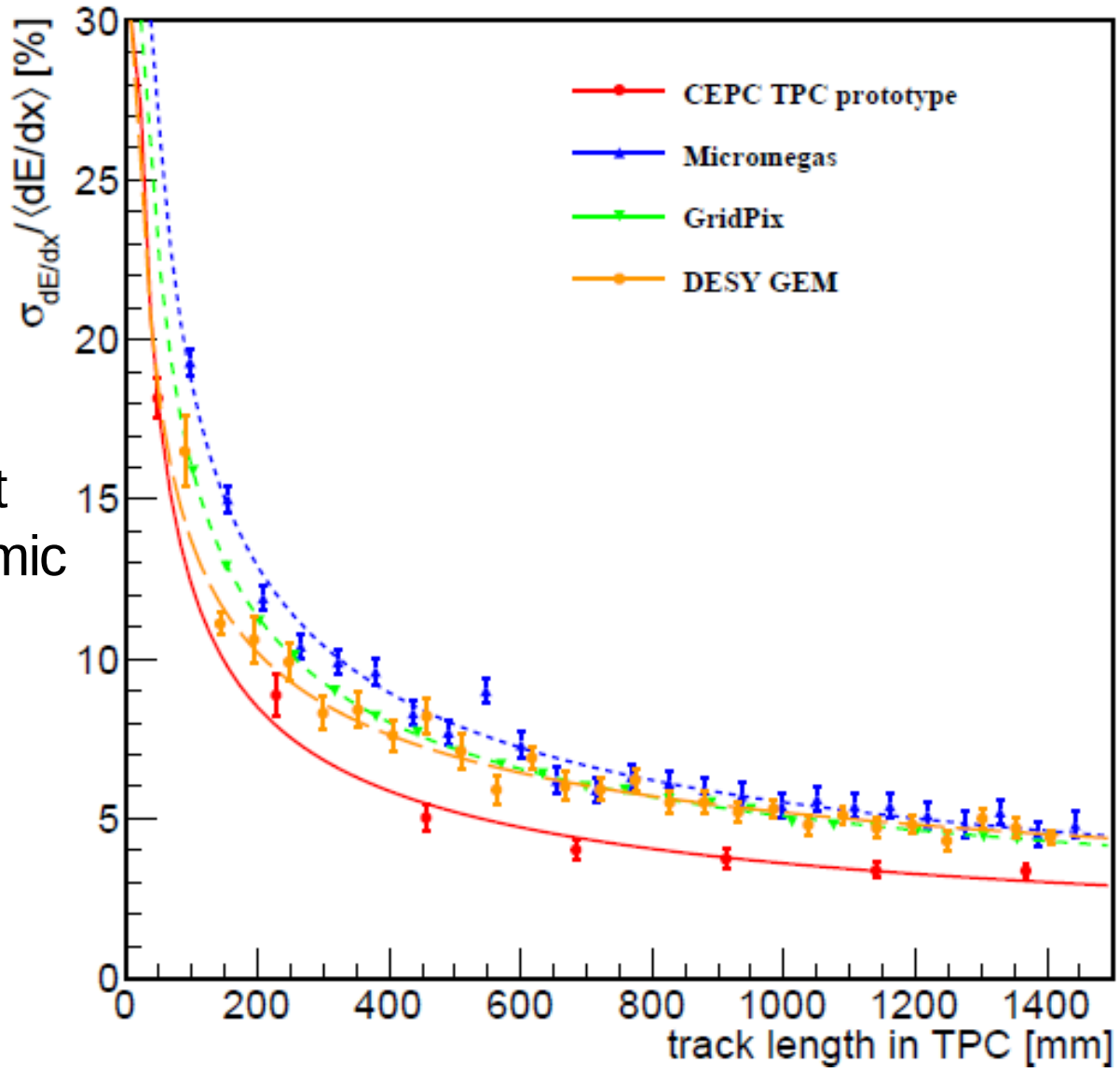
dE/dx resolution with the pseudo-tracks of the various lengths

dE /dx resolution – comparison of the existing prototypes

Next steps:

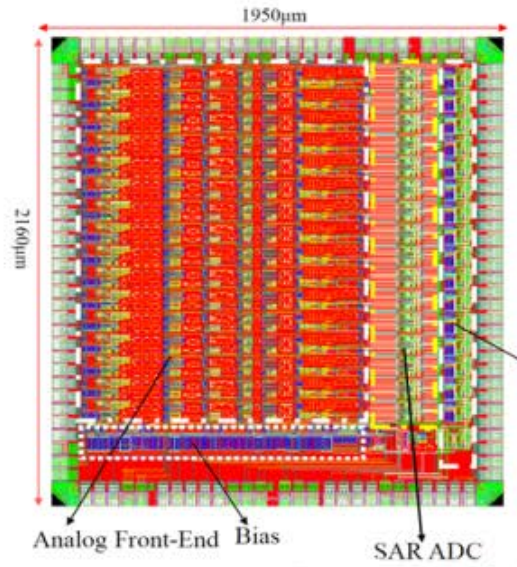
Scanning the different UV laser power to mimic the different primary electrons (and N_{eff})

Preparing the publications



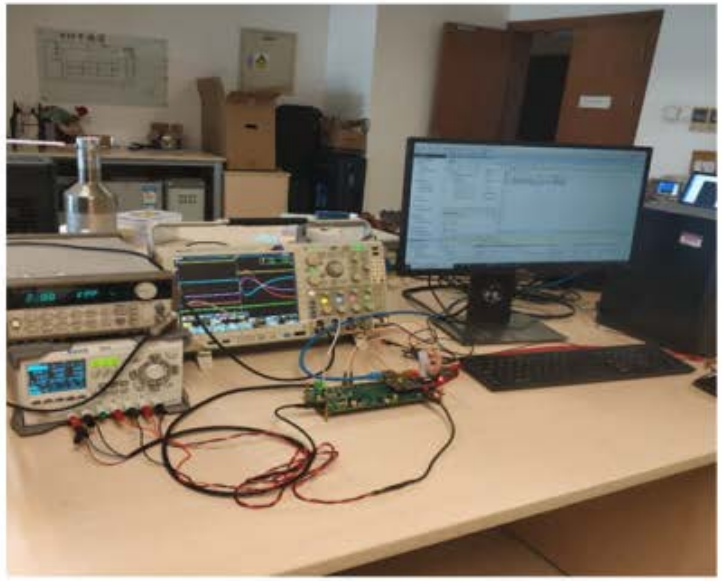
Comparison of the existing prototypes

Low power ASIC chip



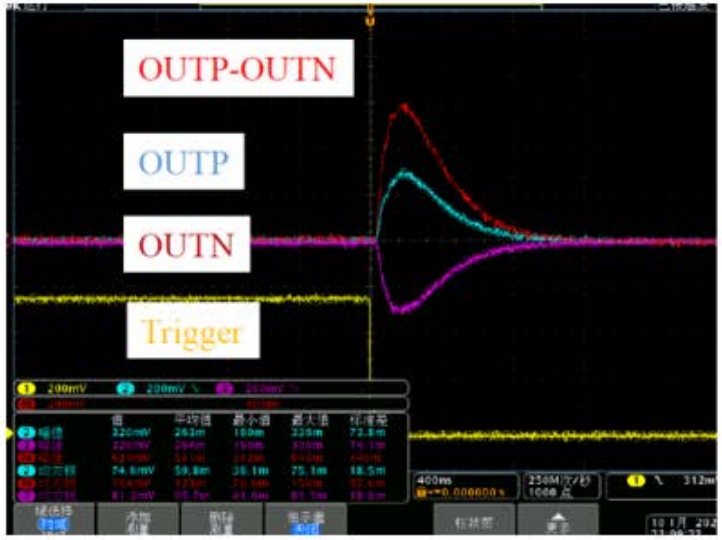
- The floor plan in layout :
  - The die size of 1950 μm x 2160 μm
  - Analog Front-End , SPI, SAR ADC, LVDS driver are supplied by separate power
- The ASIC have been taped out in November, 2019 and is being evaluated

Layout of ASIC chip



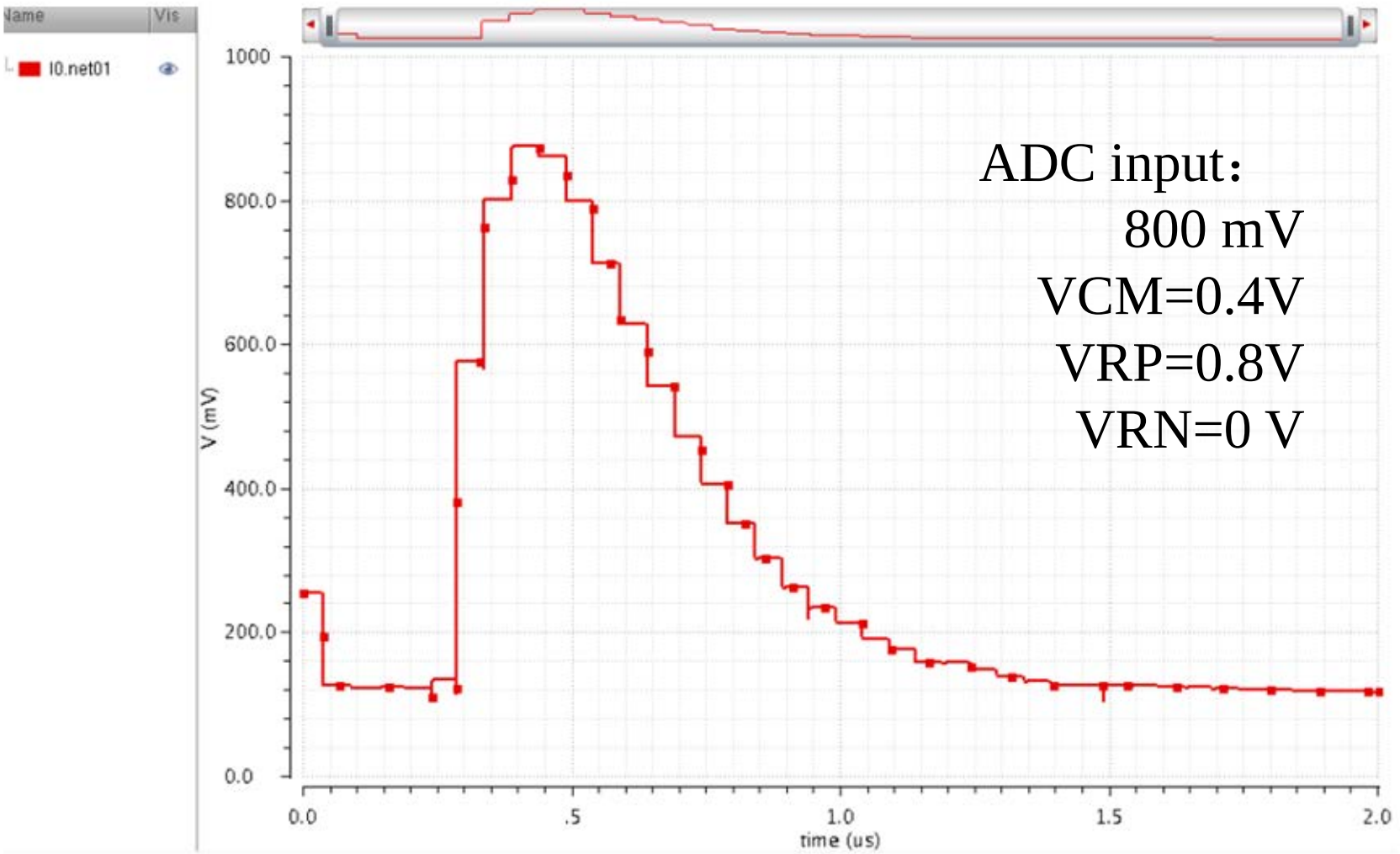
ASIC chip for TPC readout have been developed

- The power consumption is 2.33 mW/channel
  - P_{AFE} = 1.43 mW/channel
  - P_{ADC} = 0.9 mW/channel @ 40M/s
- ENC =852e @Cm = 2pF, gain =10 mV/fC and can be reduced to 474e using digital trapezoidal filter



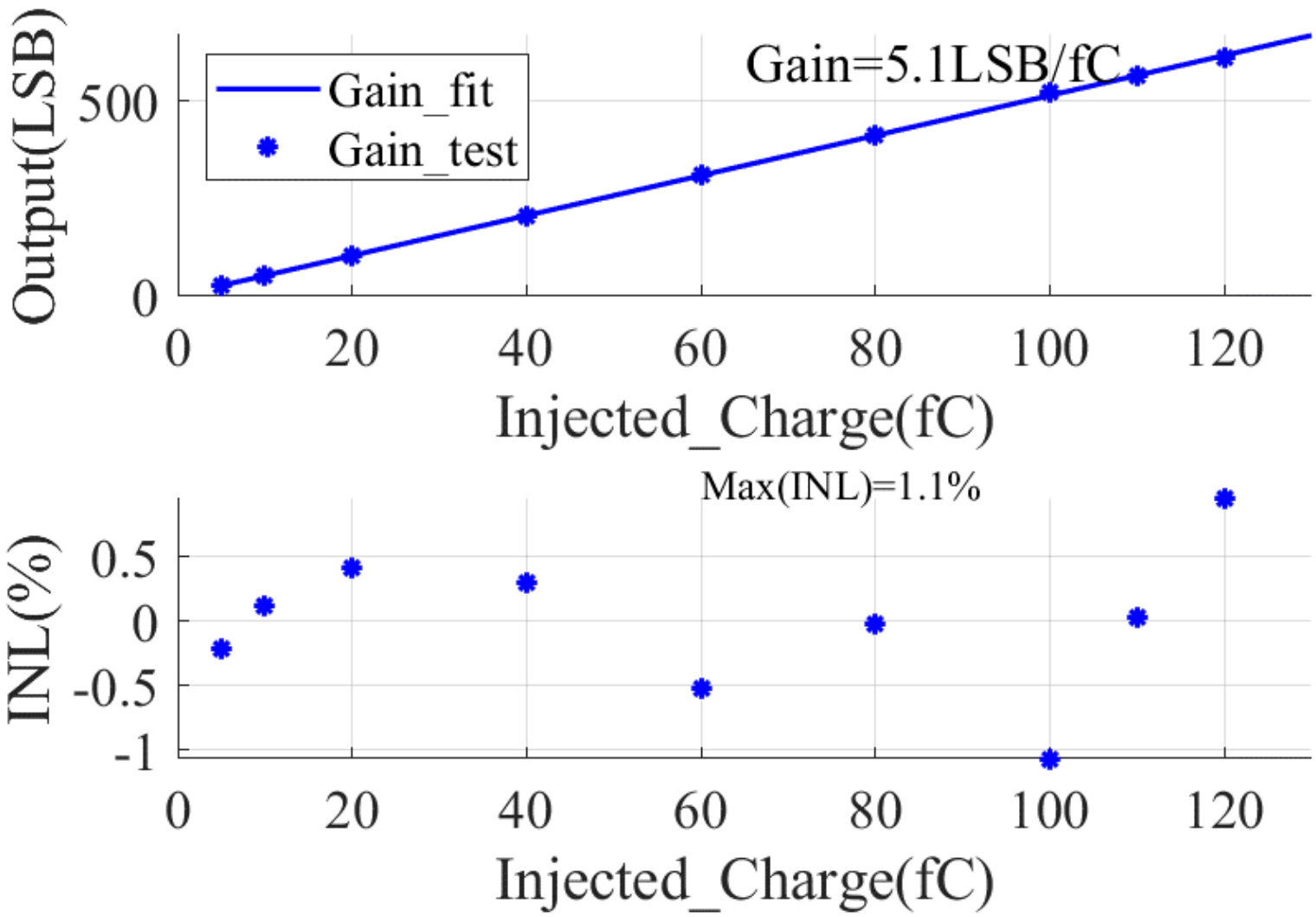
Test of the signals

Low power ASIC chip- ADC simulation

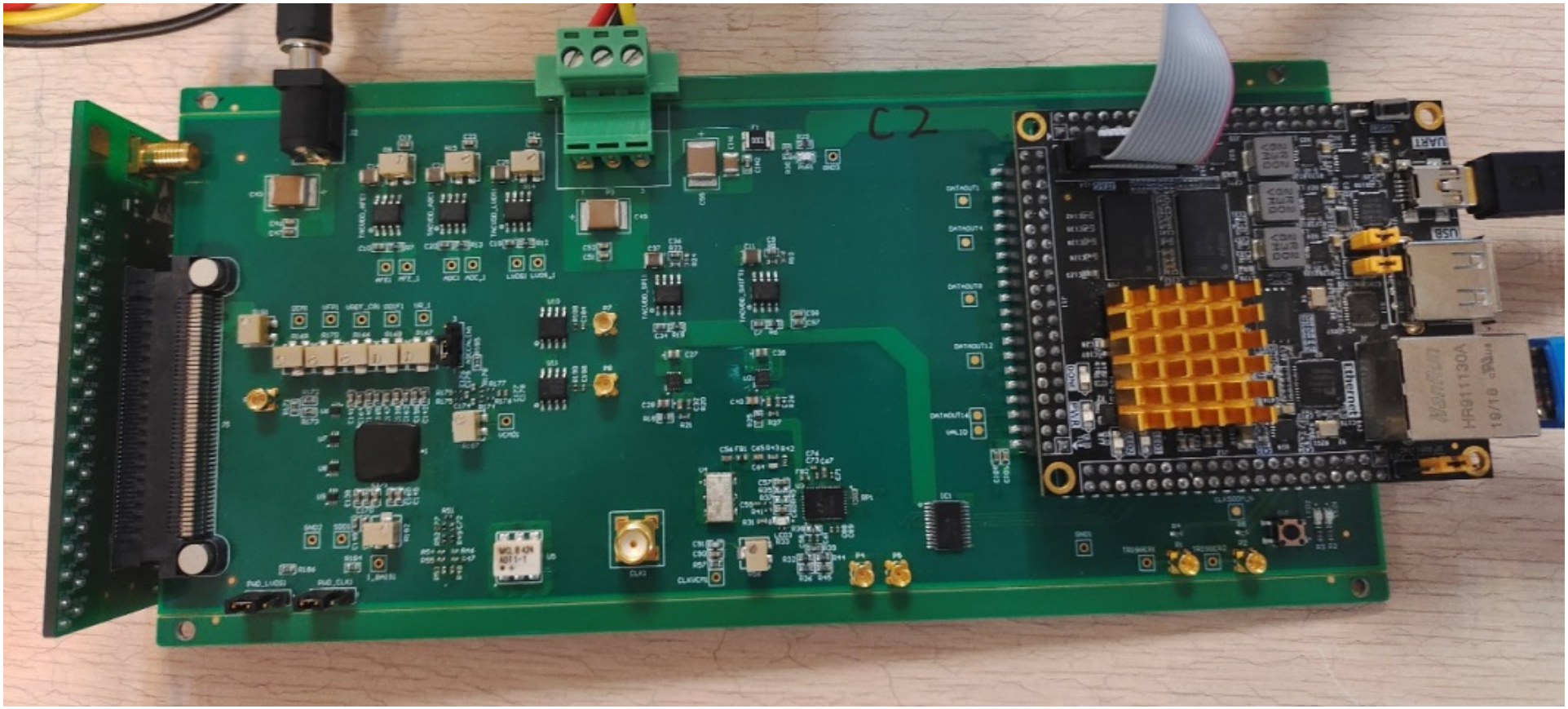


1 LSB=1600 mV/1024=1.56 mV

Low power ASIC chip- Integral Nonlinearity



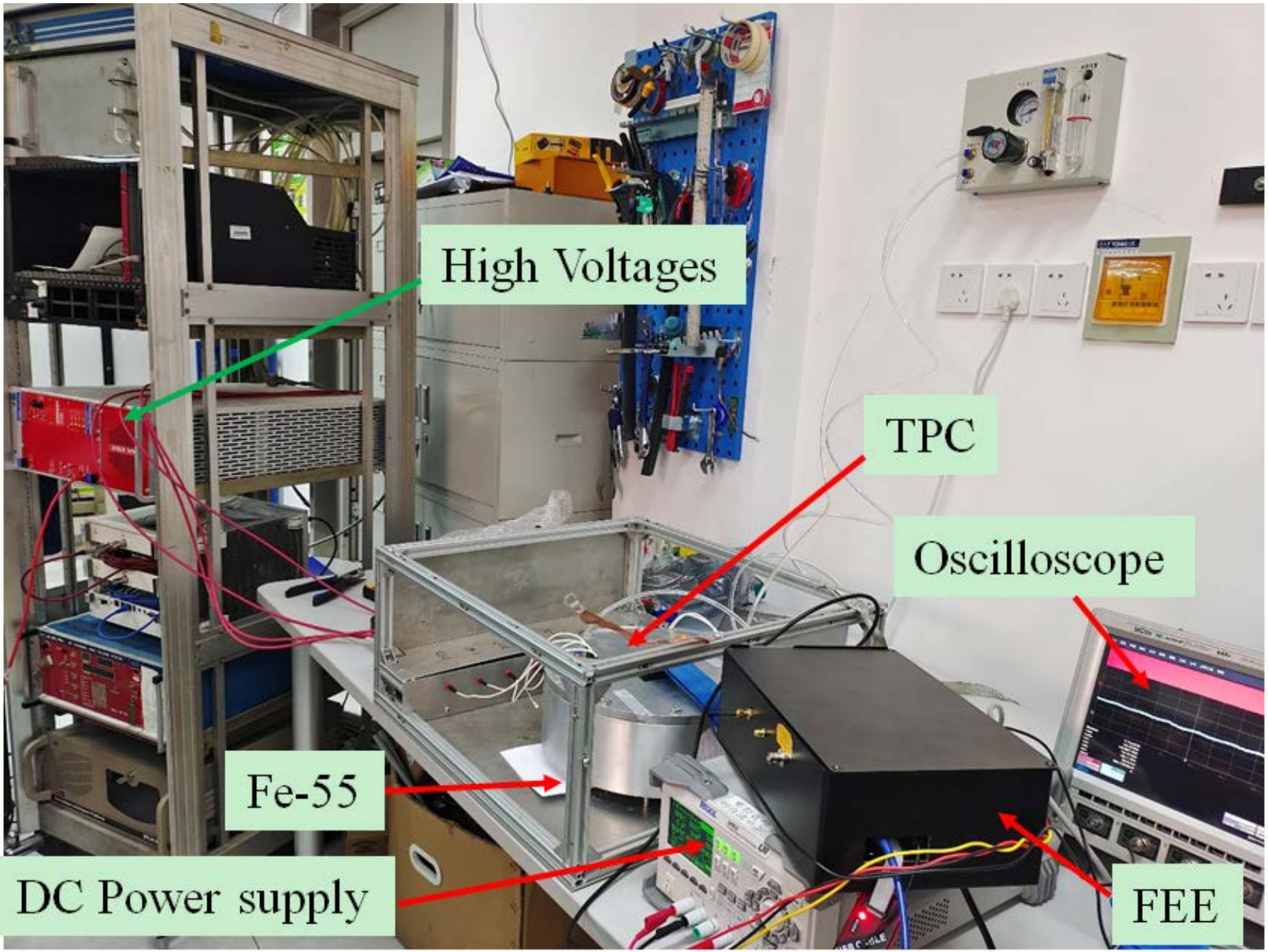
Low power ASIC chip- WASA_V0 testing board



Channels：≤128channels (64channels available)

External power supply: ±5V, ± 12V, ± 24V

Low power ASIC chip- WASA_V0 testing



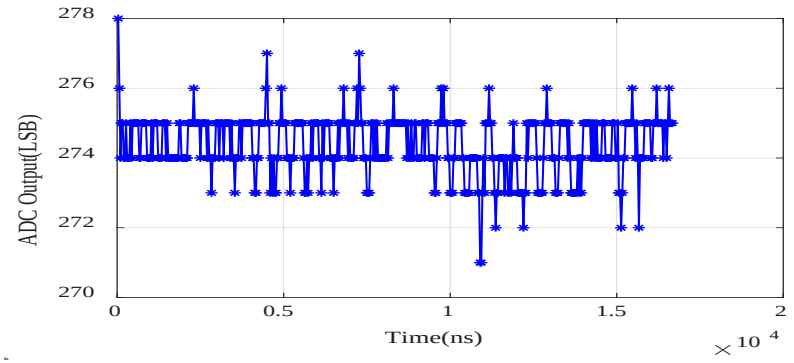
Low power ASIC chip- WASA_V0 testing

Testing parameters：

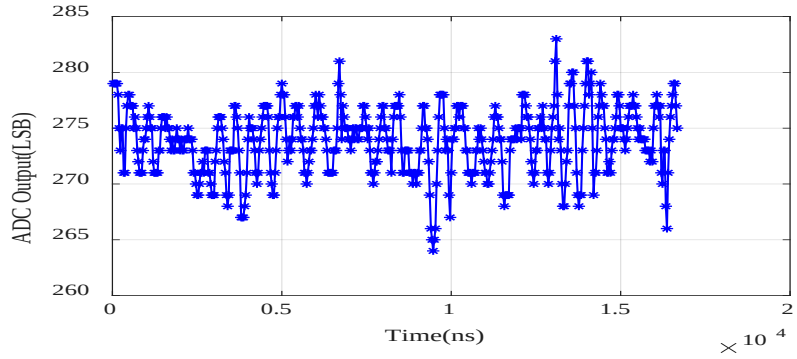
- GEMs detector: 280V-310 V
- E_{drift}： ≤280 V/cm
- Operation gases： $Ar/CF_4/iC_4H_{10}$ 95/3/2 (T2K)
- Radioactive source： ^{55}Fe@ 1mCi

Low power ASIC chip- Baseline of the noise

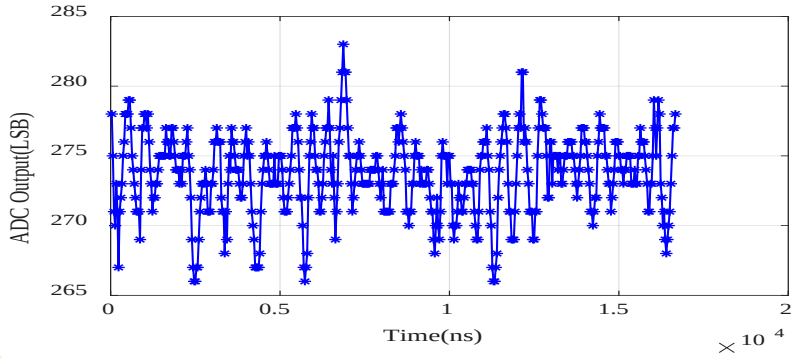
Baseline of the noise
without detector connecting



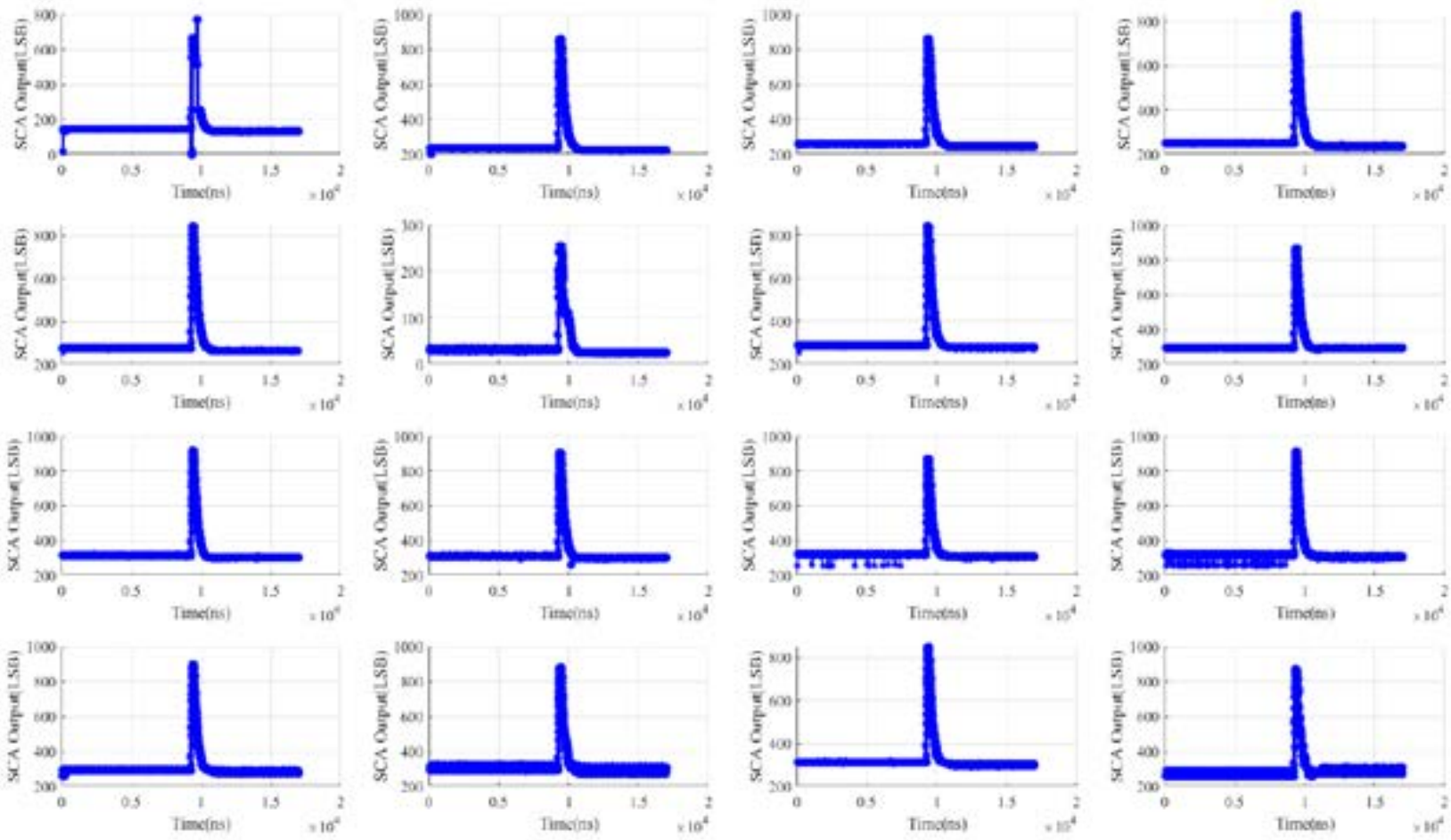
Baseline of the noise
with TPC detector connecting
@ V_{GEM}=0V@E_{drift}=0V/cm



Baseline of the noise
with TPC detector connecting
@ V_{GEM}=310V@E_{drift}=290V/cm



Low power ASIC chip- WASA_V0 testing

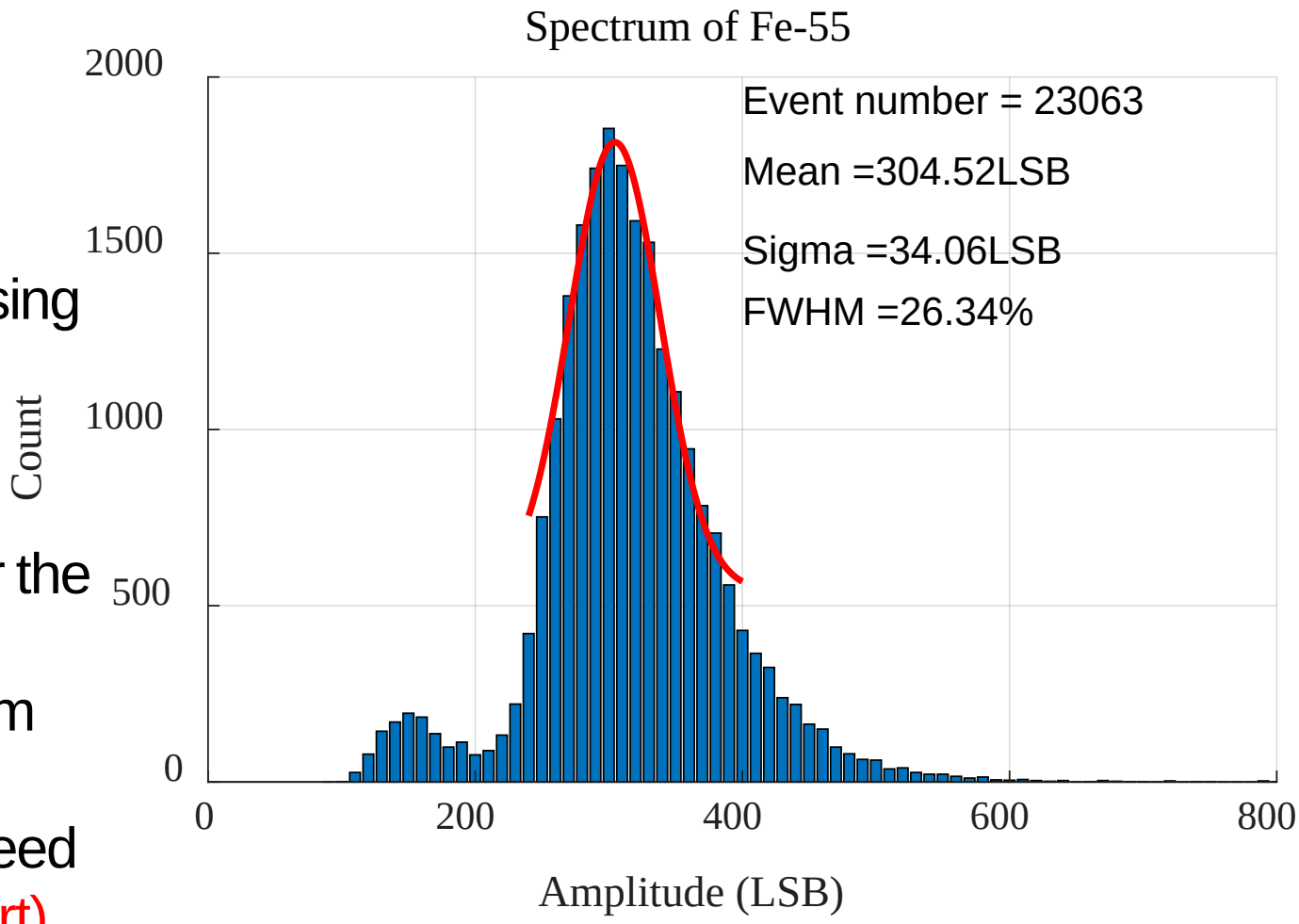


16 channels output waveform

Low power ASIC chip- preliminary results

^{55}Fe testing:
Successfully commissioned and collected signals using DAQ

Next steps:
Using collimator for the radioactive source and taking data from more channels and new DAQ to need (NO funding support)



Summary

- dE/dx study used TPC detector using 266nm UV laser
- ^{55}Fe and UV laser's energy spectrum and gain measured
- Pseudo-tracks with 220 layers and dE/dx can reach to $3.36 \pm 0.26\%$ of dE/dx by Pad size (1mm $\times$ 6mm)
- Successfully testing and collected signals using the new electronics with the lower power consumption chips

Thanks