ECAL @ DLNP

Current Status Report

N. Anfimov 08.10.2026

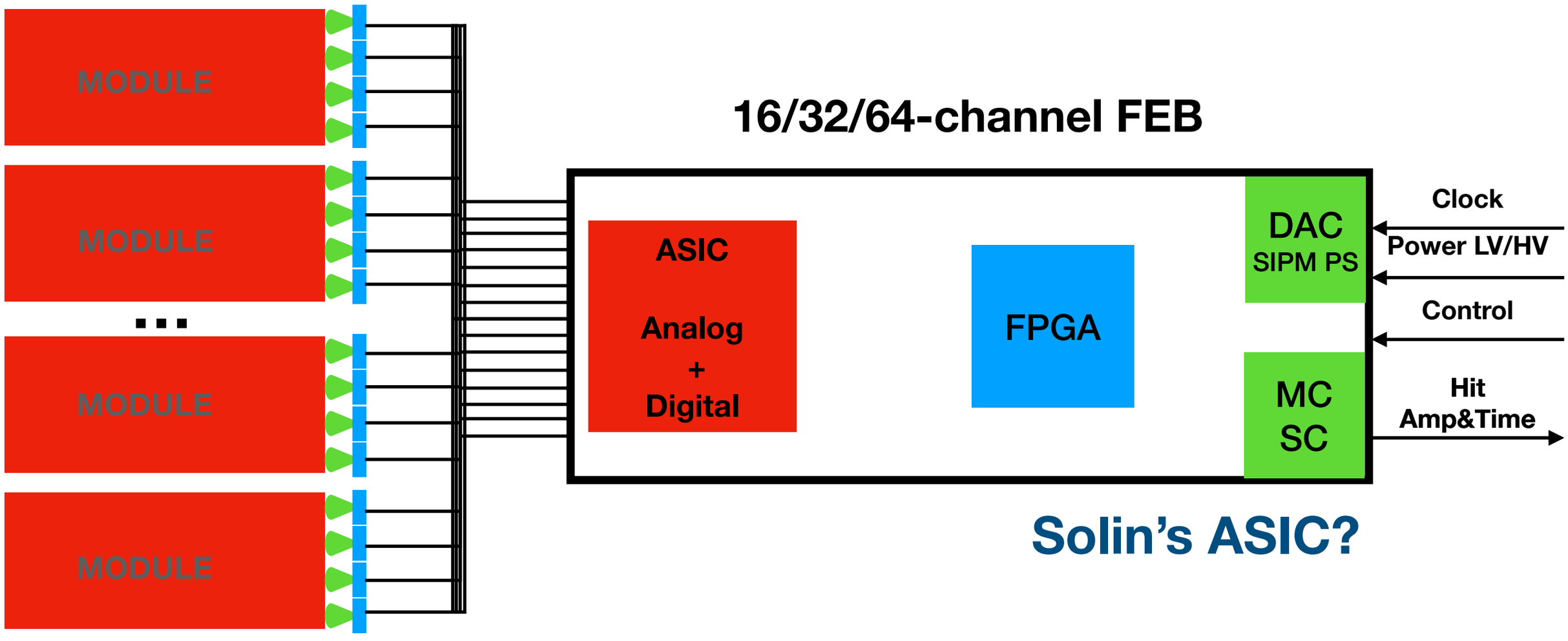
JINR
JOINT INSTITUTE
FOR NUCLEAR RESEARCH

ECAL Activities at DLNP

Responsible - N. Anfimov

Component	Main Activities	Current Status	People
Front-End Electronics (FEE)	Development of SiPM charge and timing readout	Concept and prototyping	D. Fedoseev, V. Gromov, A. Chetverikov, V. Kozhukalov + AFI (S.Bazylev)
DAQ System Interface	DAQ requirements implementation for the FEE	Requirements validation with DAQ group	V. Kozhukalov, N. Anfimov + DAQ group
Module Design	Validation of the current design; modification for the barrel part	Studies of the End-Cap design drawings; component validation	S. Sokolov, D. Fedoseev
ASIC Design	Low-power and high-density readout optimization for SiPM charge and timing	Scalable integrated electronics development — CORTAS ASIC	N. Anfimov, A. Solin, A. Selyunin
Detector Integration	Integration of detector modules, electronics, heat dissipation, cable routing	System-level validation	S. Sokolov + I&I group (V. Anosov)
Module Tests	Electronics and module characterization	Tests preparation	A. Selyunin, A. Rybnikov, V. Sharov + Yu. Davydov's group
Individual Fiber Readout	Module design development; 1.3×1.3 mm^2 SiPM development	ECAL CAD models, MC simulations, SiPM PCB layout, negotiations with JSC Integral	S. Sokolov, I. Zimin, D. Fedoseev, A. Chetverikov, N. Anfimov, A. Selyunin
Fiber Development	Attenuation length, light-trapping efficiency, mechanical properties	Qualification for detector operation	A. Selyunin, A. Rybnikov, S. Sokolov, V. Baranov + TC POF (Tver)
Monte Carlo & Simulation	Detector simulations, electronics-response simulations; reconstruction studies	Validation of detector design and performance	A. Maltsev, I. Zimin, Yu. Koulchitskiy, L. Simbiryatin
International Collaboration	Coordination with Chinese and Shandong partners, joint R&D, equipment exchange	Collaborative roadmap development, Modules shipment	A. Guskov, N. Anfimov, A. Selyunin, K. Kuznetsova
Components Procurement	Procurement of SiPMs, Kuraray fibers, Electronic components	Procurement process at JINR	K. Kuznetsova, A. Selyunin, D. Fedoseev, A. Chetverikov

Readout Electronics
(D. Fedoseev, A. Chetverikov, V. Kozhukalov, V. Gromov)
+ DAQ group.



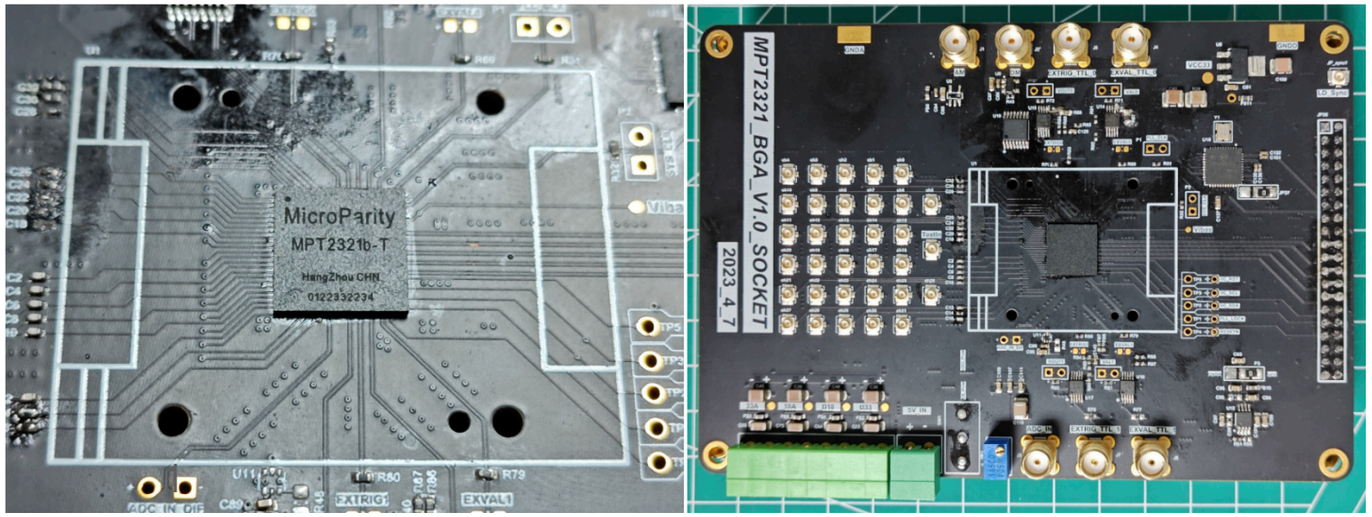
Solin's ASIC?

L1 can support 128/256/512/1024 cells (8/16 ports)

ASIC MPT2132 (Micro Parity)

Feature

- 32-channel analog input channel
- 50PS precision TDC
- 12bit precision ADC
- On-chip signal processing
- Standard IIC interface
- LVDS data interface
- Max. 12 Mcps event rate
- 200M data transfer rate
- Maximum charge measured dynamic range of 1.8 nC
- Minimum detectable signal range of 4 fC



Исх. №7 от 26.01.2026г.

Коммерческое предложение

ООО «НТЦ АРСЕНАЛ» предлагает Вашему вниманию:

	Наименование заказчика	Наименование поставщика	Кол-во заказчика	Кол-во поставщика	Цена (руб./шт., без НДС)	Сумма, руб. без НДС	Производитель	Срок готовности к отгрузке к.дн.	Год	Примечание
1	Микросхема MPT 2321	Микросхема MPT2321	10	10	322 725,42	3 227 254,20	Microparity	77	24+	

Итого без НДС: 3 227 254,2 руб.
НДС 22%: 709 995,92 руб.
Итого с НДС: 3 937 250,12 руб.

2000k$ via China partners (Dongdong)

Custom ASIC design (A. Solin, N. Anfimov)

CORTAS - COmbined Readout for Timing and Amplitude Signals

Brief ASIC Description

The objective is to develop a **multi-channel mixed-signal ASIC** for the readout of **silicon photomultipliers (SiPMs)**.

The ASIC shall include **8 channels** with **multi-range dynamic gain selection** (**4 parallel gain paths with automatic switching**), providing both:

- **charge measurement** (**10/12-bit ADC**)
- **time measurement** (**TDC resolution ~25 ps**)

Additionally, **preselective gain configuration** shall be supported.

The output shall be a **streaming digital data flow**.

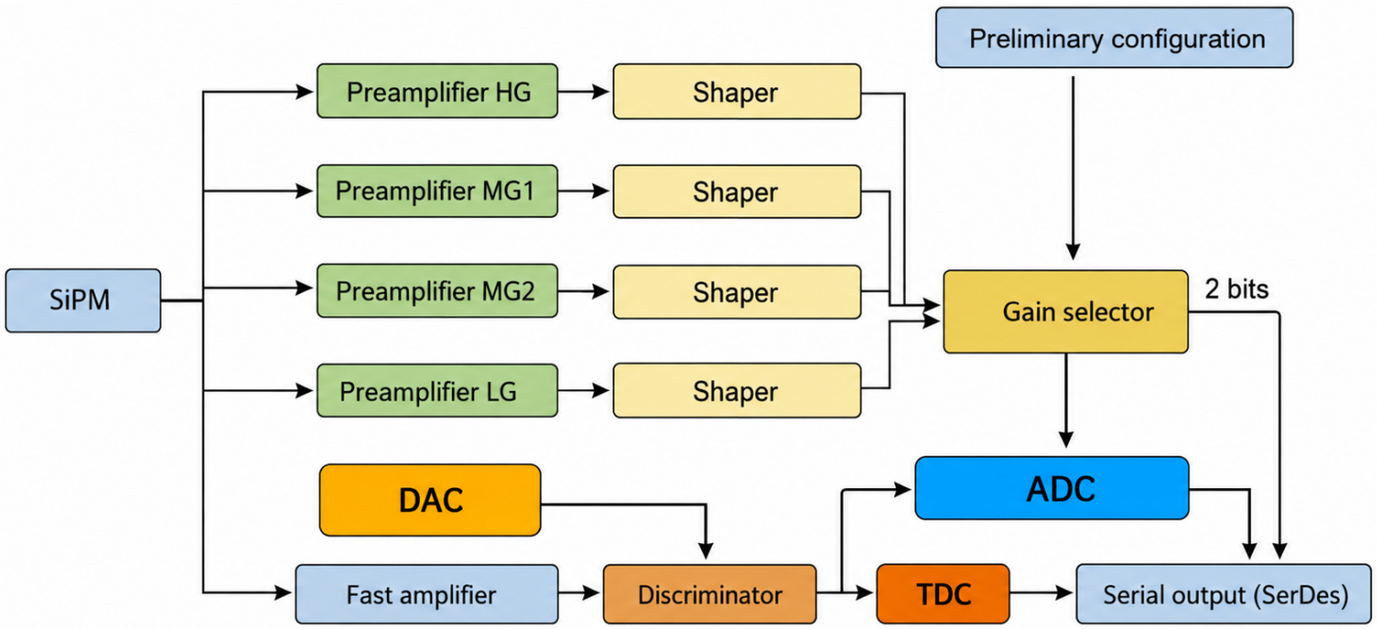
The ASIC shall include:

- built-in **fast auto-trigger**
- **SPI control interface**
- throughput of at least **1 M event/s per channel**

A wide dynamic range (**>1:65,000**) is required, with:

- low noise (**~3 fC at 500 pF input load**)
- timing jitter **~35 ps (500 pF input)**

Target technology: **180 nm CMOS**



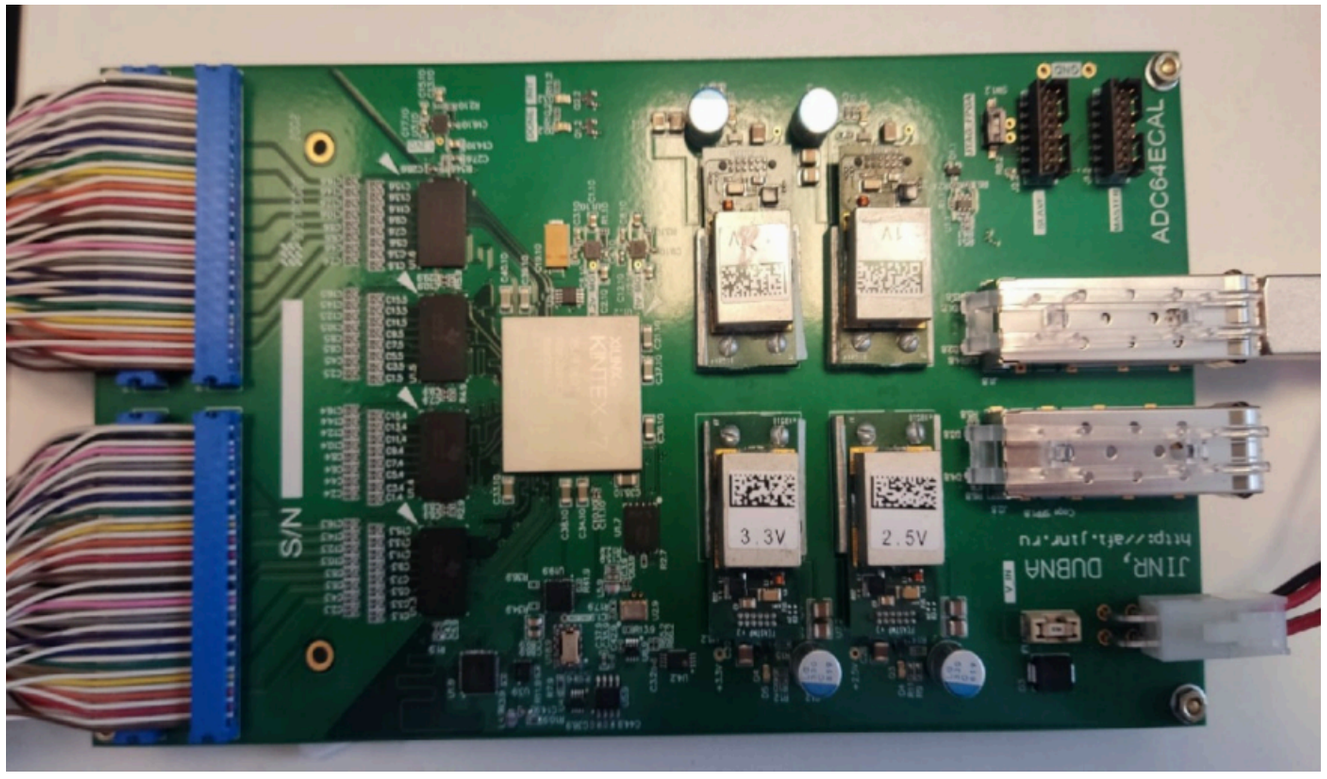
Technical Requirements

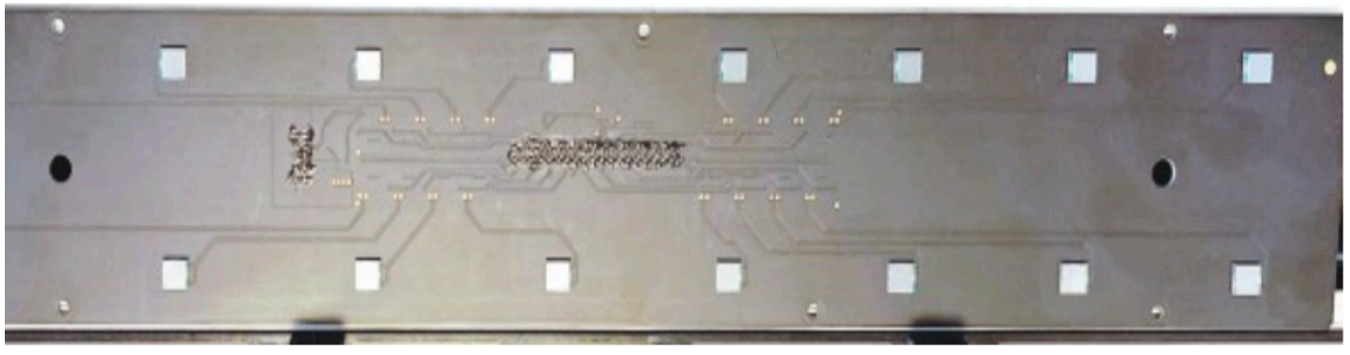
Parameter	Requirement
Channels	8
Detector / Rate	SiPM, ≥1 M event/s/channel (FIFO buffered), recovery time ~100 ns @ 500 pF
Supported SiPM capacitance	0.1–10 nF
Analog front-end	4 gain ranges (dynamic switching or preselective): 0–2 pC, 0–20 pC, 0–200 pC, 0–2000 pC
Shaping time	30 ns
ADC (SAR)	≥10 bit, 31.25 MHz
DAC resolution	10 bit (auto-trigger threshold, TDC threshold)
Fast amplifier	≥200 MHz bandwidth, configurable gain ×1–×100
ADC requirements	INL ≤1 LSB, DNL ≤0.5 LSB
TDC	LSB ~25 ps; DLL calibration; channel drift <100 ppm/°C
External timing	External trigger input (T0, 9 TDC) / external clock for coarse counter
Dynamic range	≥1:65,000 (equivalent ≥16 bits)
Noise (ENC)	~3 fC (500 pF load, spectroscopy channel)
Jitter (σ)	≤35 ps (500 pF timing channel)
Power consumption	≤30 mW/channel
System clocks	31.25 / 125 MHz (125 MHz White Rabbit reference)
Supply voltages	3.3 V / 1.8 V
Digital output (DAQ)	LVDS serial bitstream, SerDes 1×1 Gbps
Control interface	SPI (register programming)
Technology	CMOS 180 nm
DFT / testability	scan chains, test pulse injection (100 pC)

JINR will pay first part soon.

ADC64ECAL + E_CAL_V43_T5

- Adaptation to a triggerless mode
- ADC (ADS52J90): ~50 mW/channel; ADC + FPGA total: ~125 mW/ channel
- Differential shapers (THS4531IRUN): ~2–3 mW/channel
- SiPM power: <100 mW per 16 channels
- Rate per ADC: ~64 × 30 kcps ≈ 2 MFr/s
- MAF integration algorithm enables an energy threshold
- Timing: WR clock → σ ≈ 2.3 ns







ASIC AFE5818

(V. Kozhukalov, A. Chetverikov, D. Fedoseev, V. Gromov)

1 Features

- 16-Channel, Complete Analog Front-End:
  - LNA, VCAT, PGA, LPF, ADC, and CW Mixer
- LNA with Programmable Gain:
  - Gain: 24 dB, 18 dB, and 12 dB
  - Linear Input Range: 0.25 V_{PP}, 0.5 V_{PP}, and 1 V_{PP}
  - Input-Referred Noise: 0.63 nV/$\sqrt{Hz}$, 0.7 nV/$\sqrt{Hz}$, and 0.9 nV/$\sqrt{Hz}$
  - Programmable Active Termination
- Voltage-Controlled Attenuator (VCAT): 40 dB
- Programmable Gain Amplifier (PGA): 24 dB and 30 dB
- Total Signal Chain Gain: 54 dB (max)
- 3rd-Order, Linear-Phase LPF:
  - 10 MHz, 15 MHz, 20 MHz, 30 MHz, 35 M and 50 MHz
- Analog-to-Digital Converter (ADC):
  - 14-Bit ADC: 75-dBFS SNR at 65 MSPS
  - 12-Bit ADC: 72-dBFS SNR at 80 MSPS
- LVDS Interface Maximum Speed of 1 Gbps
- Noise and Power Optimizations (Full-Chanr
  - 140 mW/Ch at 0.75 nV/$\sqrt{Hz}$, 65 MSPS
  - 91.5 mW/Ch at 1.1 nV/$\sqrt{Hz}$, 40 MSPS

2 Applications

- Medical Ultrasound Imaging
- Nondestructive Evaluation Equipment
- Sonar Imaging Equipment
- Multichannel, High-Speed Data Acquisition

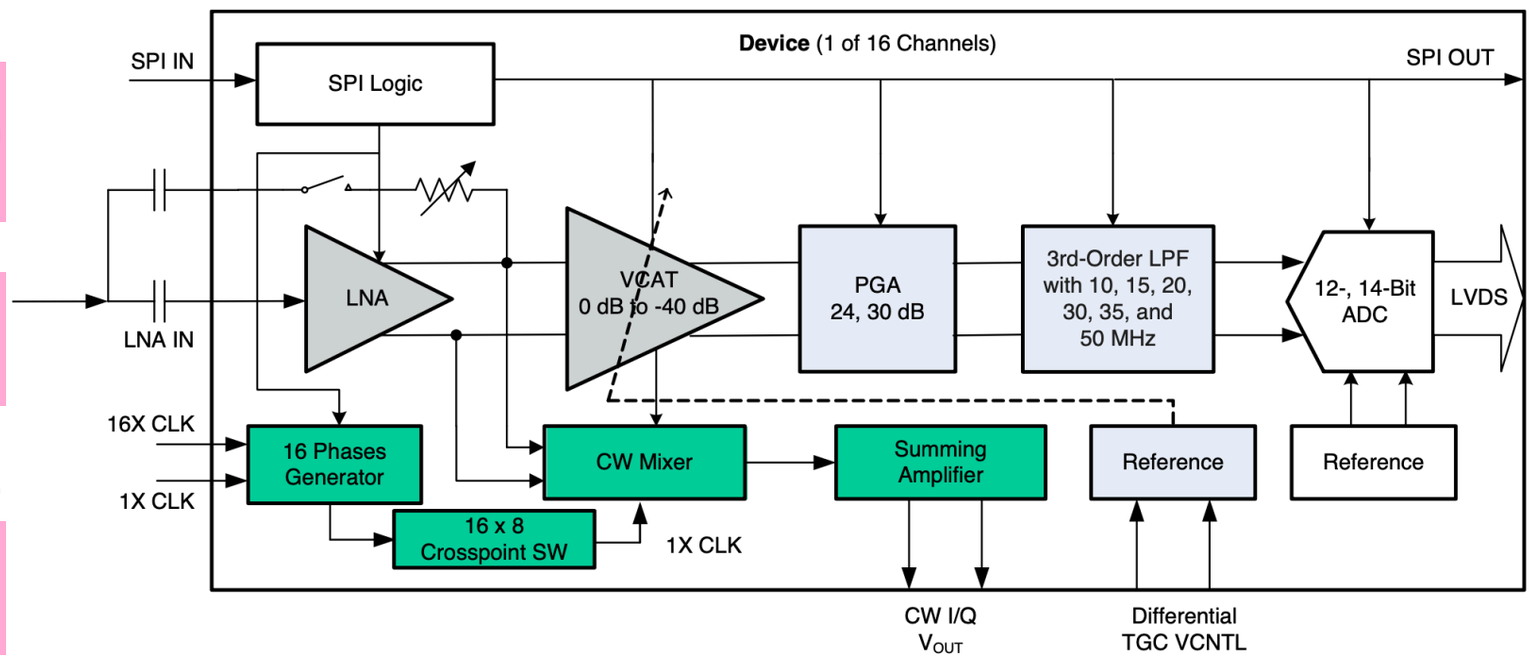
3 Description

The AFE5818 is a highly-integrated, analog front-end (AFE) solution specifically designed for ultrasound systems where high performance and small size are required. The device integrates a complete time-gain-control (TGC) imaging path and a continuous wave Doppler (CWD) path. The device also allows various power and noise combinations to be selected to optimize system performance. Therefore, the AFE5818 is a suitable ultrasound AFE solution for high-end and portable systems

Device Information(1)

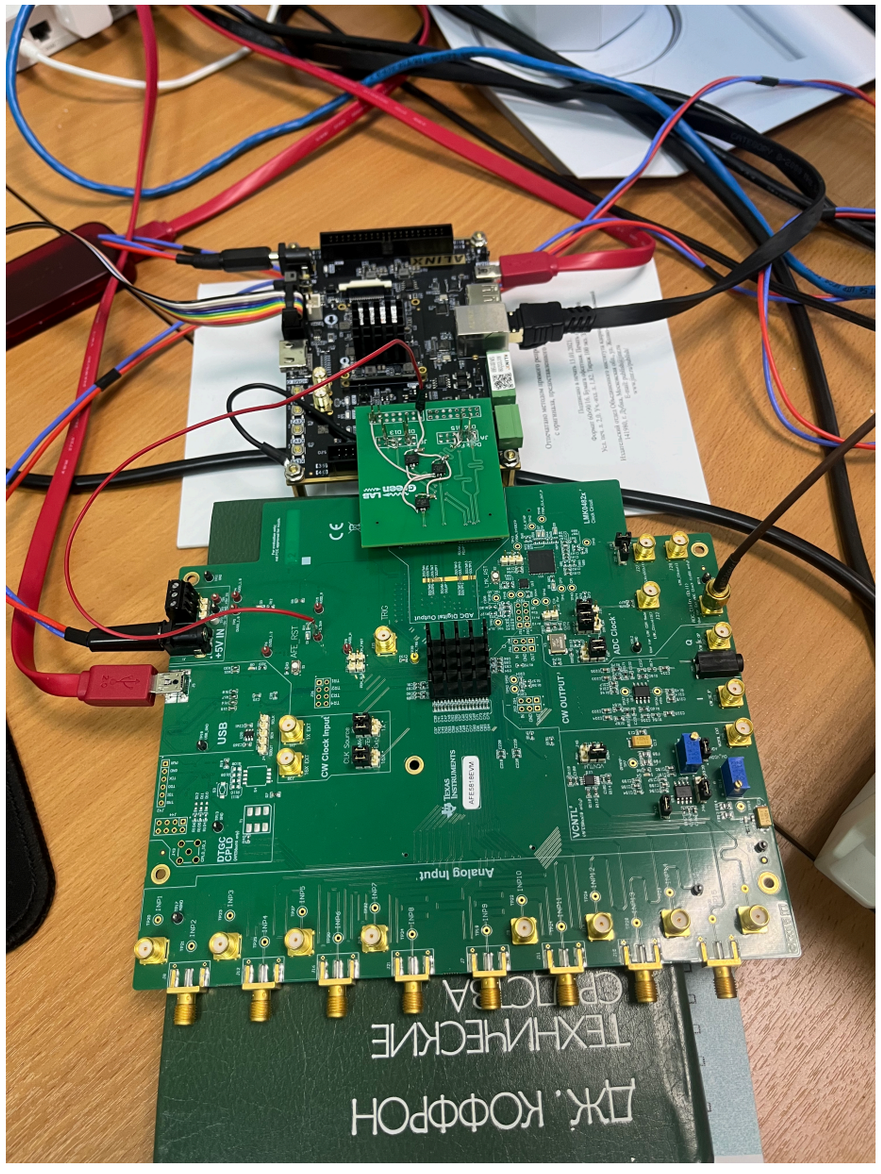
PART NUMBER	PACKAGE	BODY SIZE (NOM)
AFE5818	NFBGA (289)	15.00 mm × 15.00 mm

Simplified Block Diagram



ASIC AFE5818

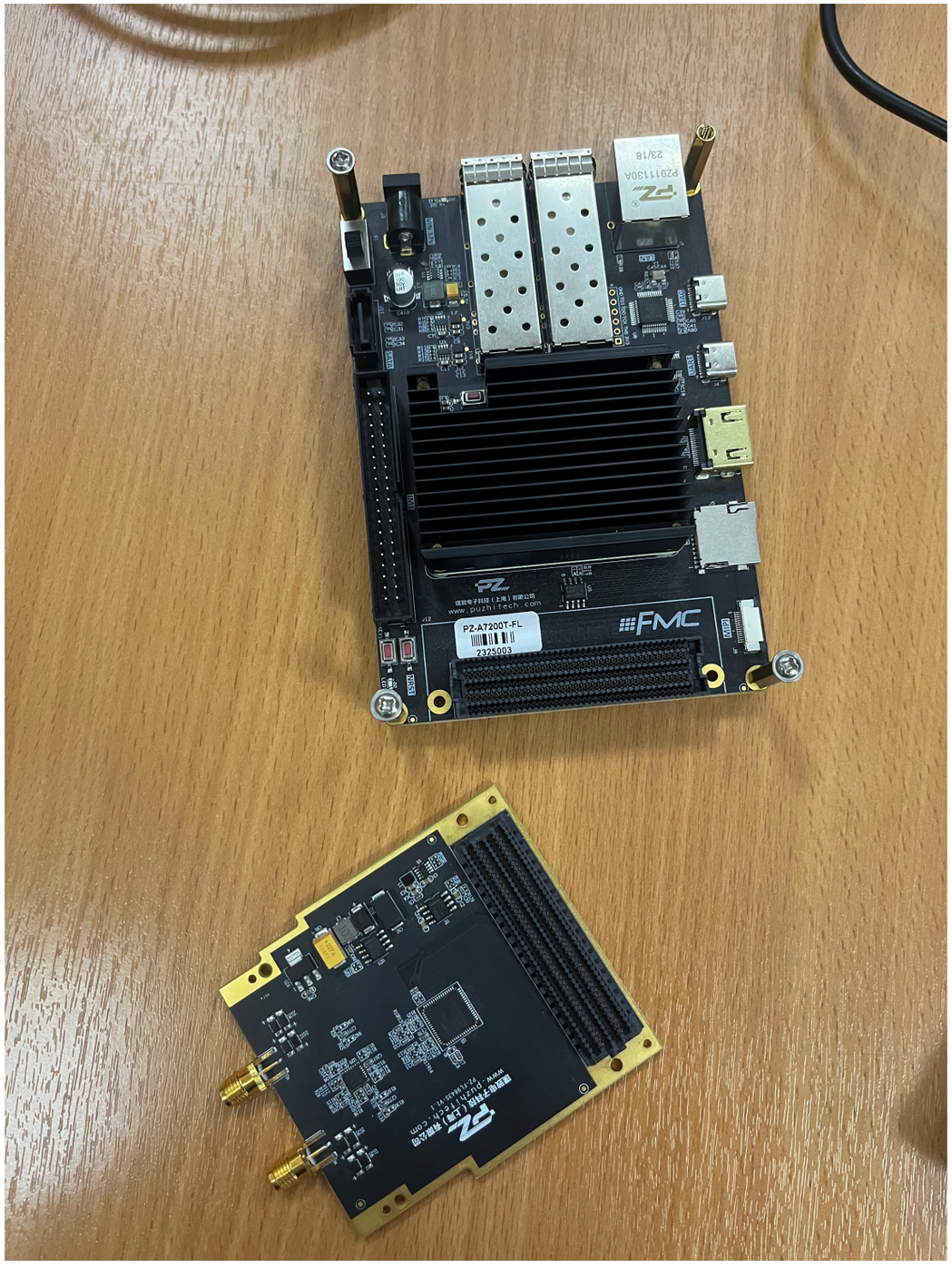
(V. Kozhukalov, A. Chetverikov, D. Fedoseev, V. Gromov)

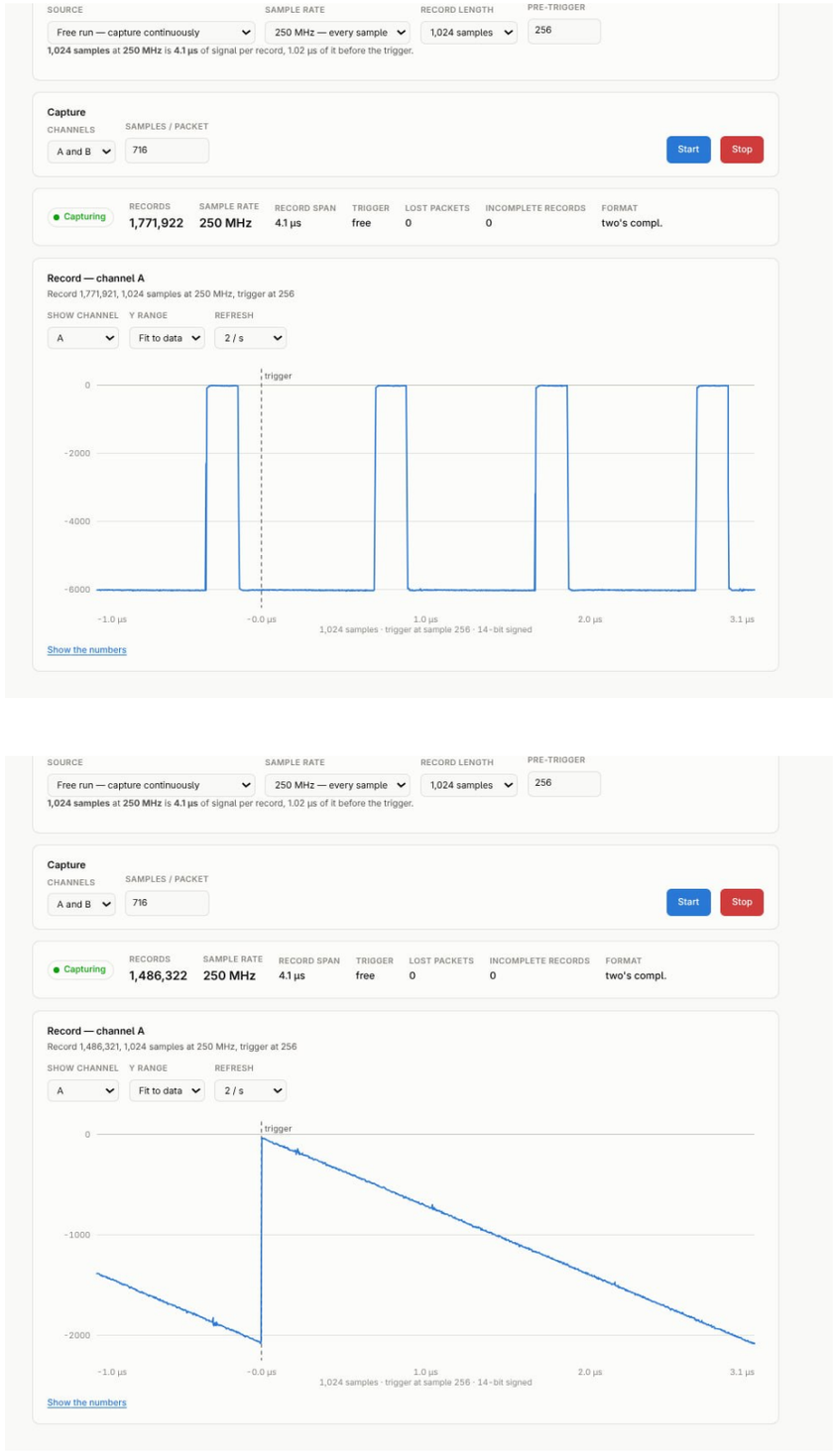




ADC Development

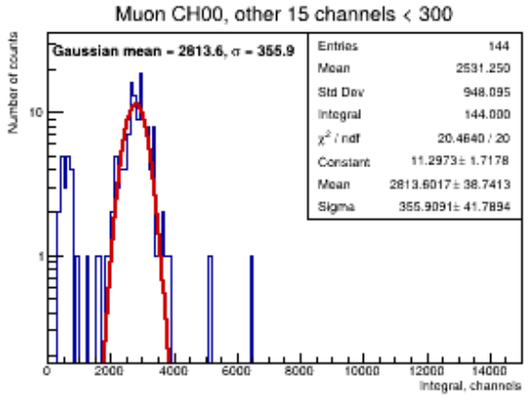
(V. Kozhukalov, A. Chetverikov, D. Fedoseev, V. Gromov)

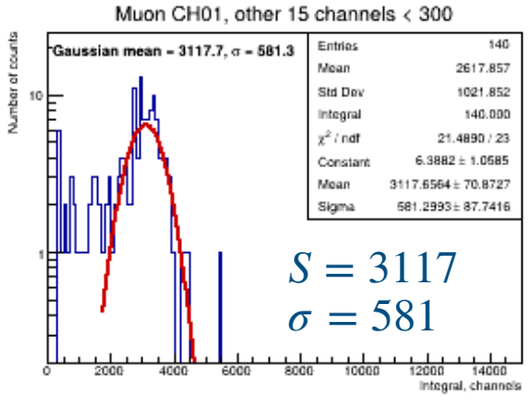




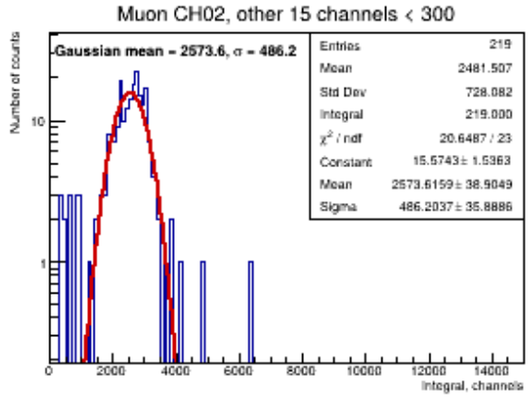
Light yield cross-checking

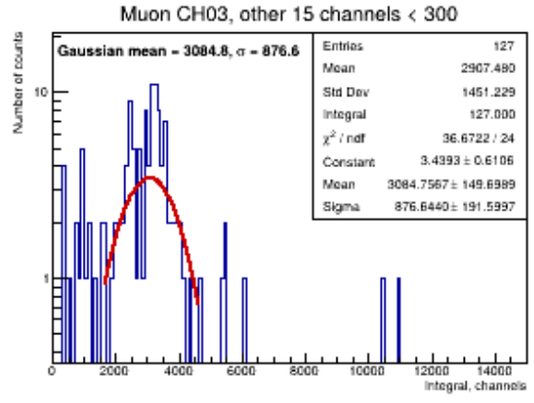
Analisys (A. Rybnikov)

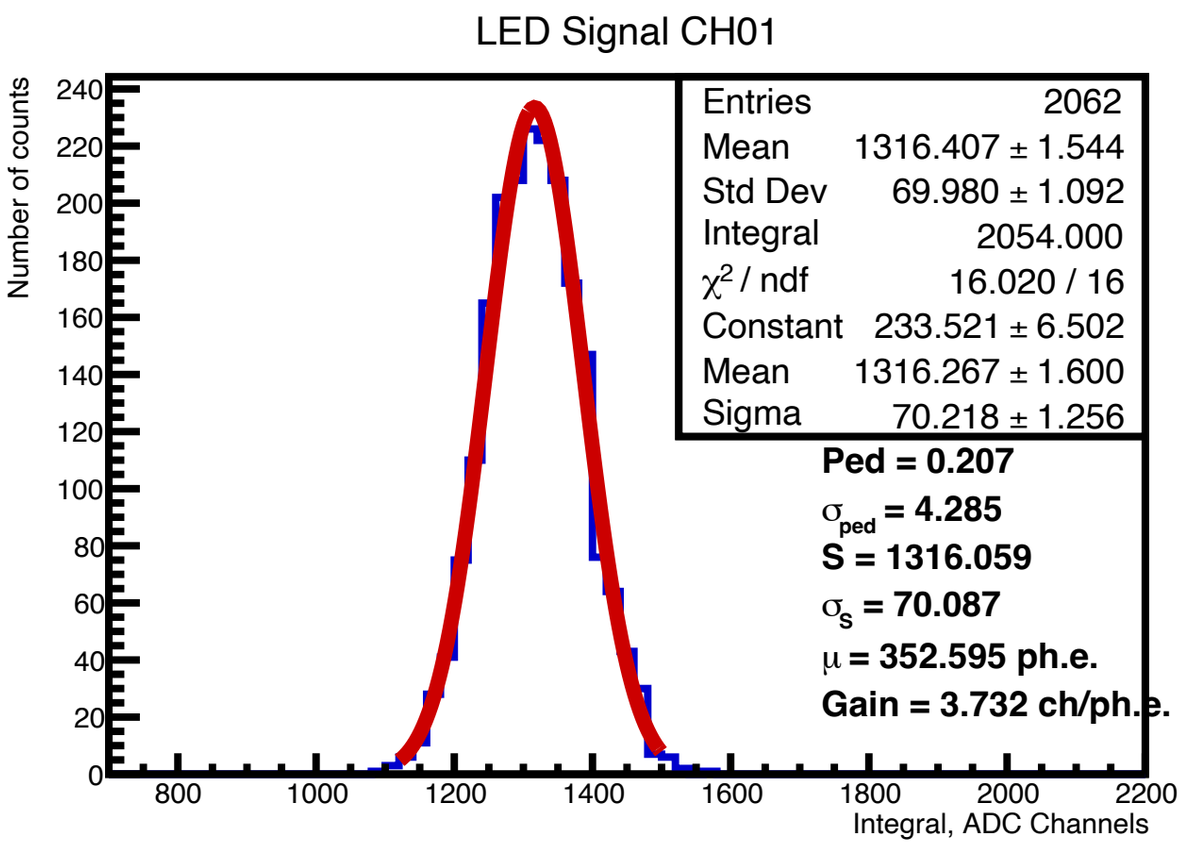




$S = 3117$
$\sigma = 581$







Ideal poisson

$\mu_p = \sigma_p^2$

Measured:

$S = \mu_p \times Gain, \sigma = \sigma_p \times Gain$

From which

$$\mu_p = \left(\frac{S}{\sigma}\right)^2, Gain = \frac{S}{\mu_p}$$

From LED:

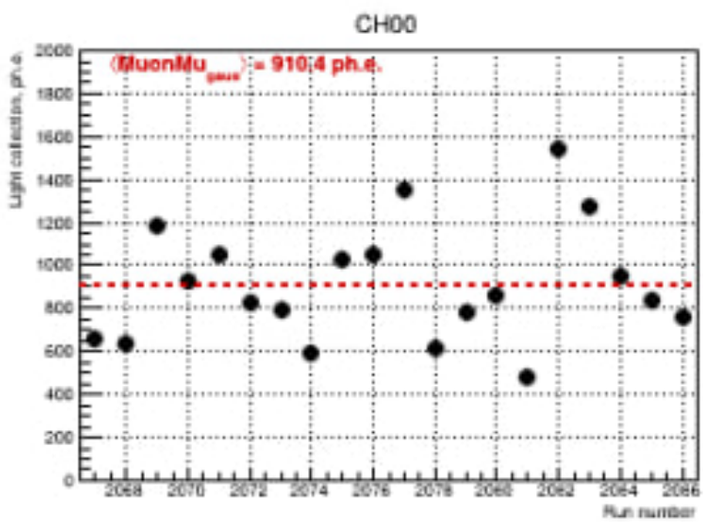
$\mu_p = 352, Gain = 3.7$

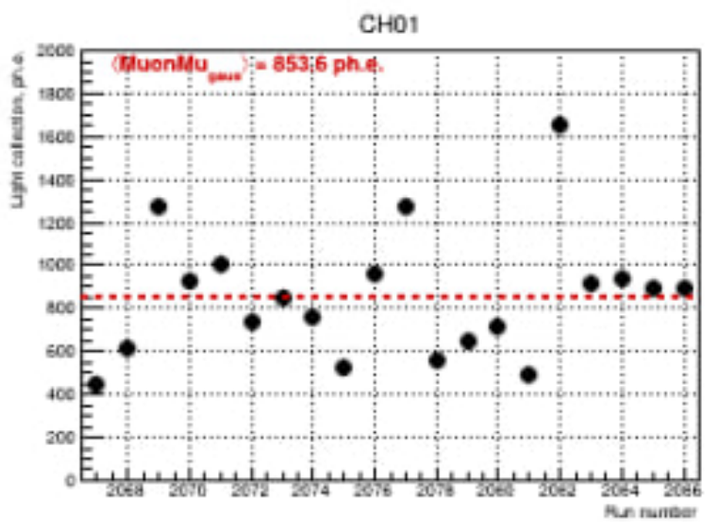
Muon light yield:

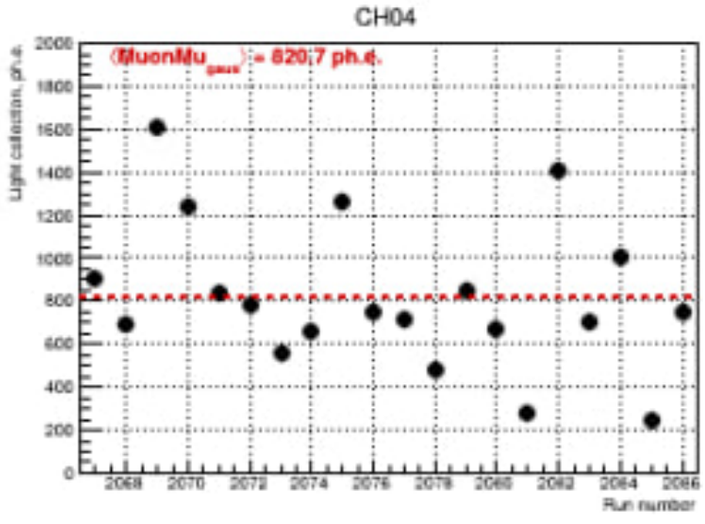
$\mu_{MIP} = 3117/3.7 = 842\ ph.e.$

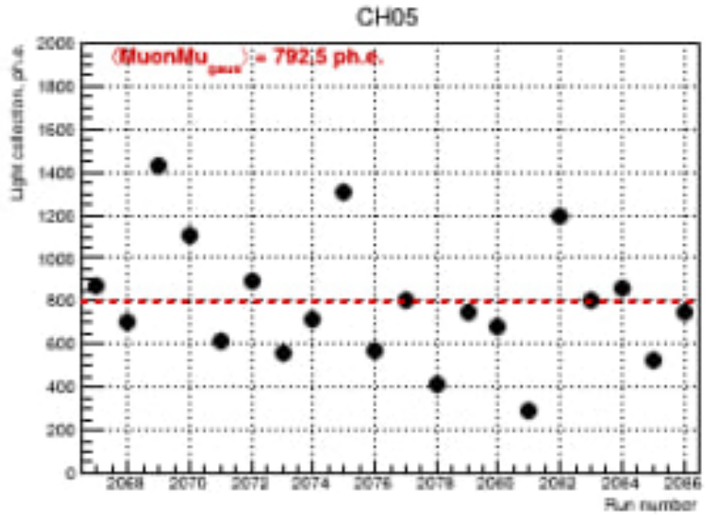
Light yield cross-checking

Analisys (A. Rybnikov)









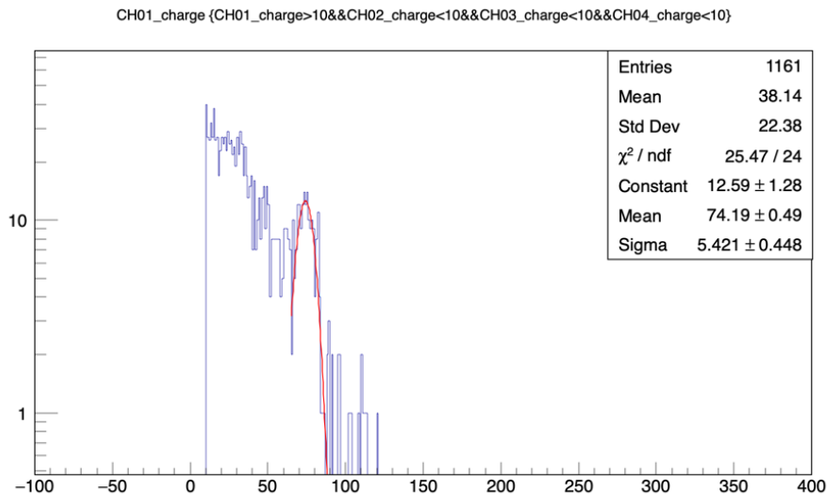
Lower Estimate

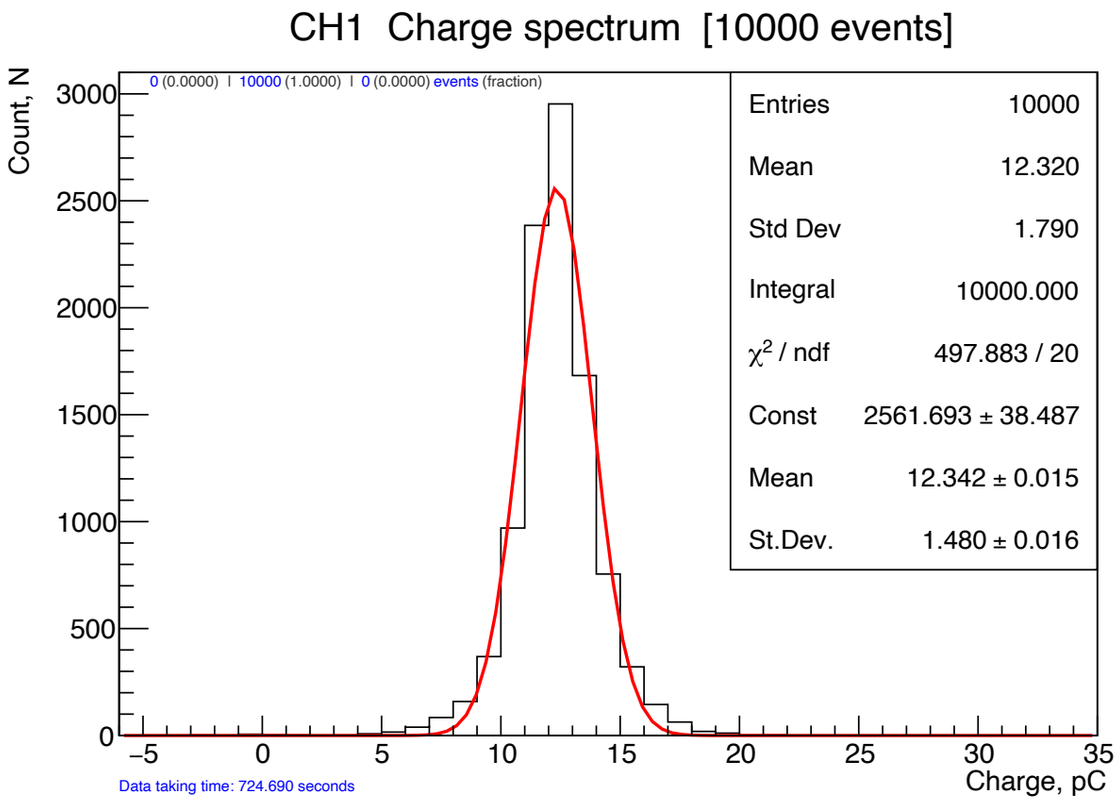
$$< \mu_{MIP} > \approx 800 - 900 \; ph.e.$$

$$< \mu_{1GeV} > \approx 3400 - 3900 \; ph.e.$$

Light yield cross-checking

Analisys (A. Rybnikov)





Ideal poisson

$$\mu_p = \sigma_p^2$$

Measured:

$$S = \mu_p \times Gain, \sigma = \sigma_p \times Gain$$

From which

$$\mu_p = \left(\frac{S}{\sigma}\right)^2, Gain = \frac{S}{\mu_p}$$

From LED:

$$\mu_p = 70,\ Gain = 0.18$$

Muon light yield:

$$\mu_{MIP} = 74/0.18 = 415$$ **ph.e???**

1GeV = 1800 ph.e ???

We plan to run testing bench at DLNP

Testing/production room #3 bld.3

Responsible (A. Rybnikov)



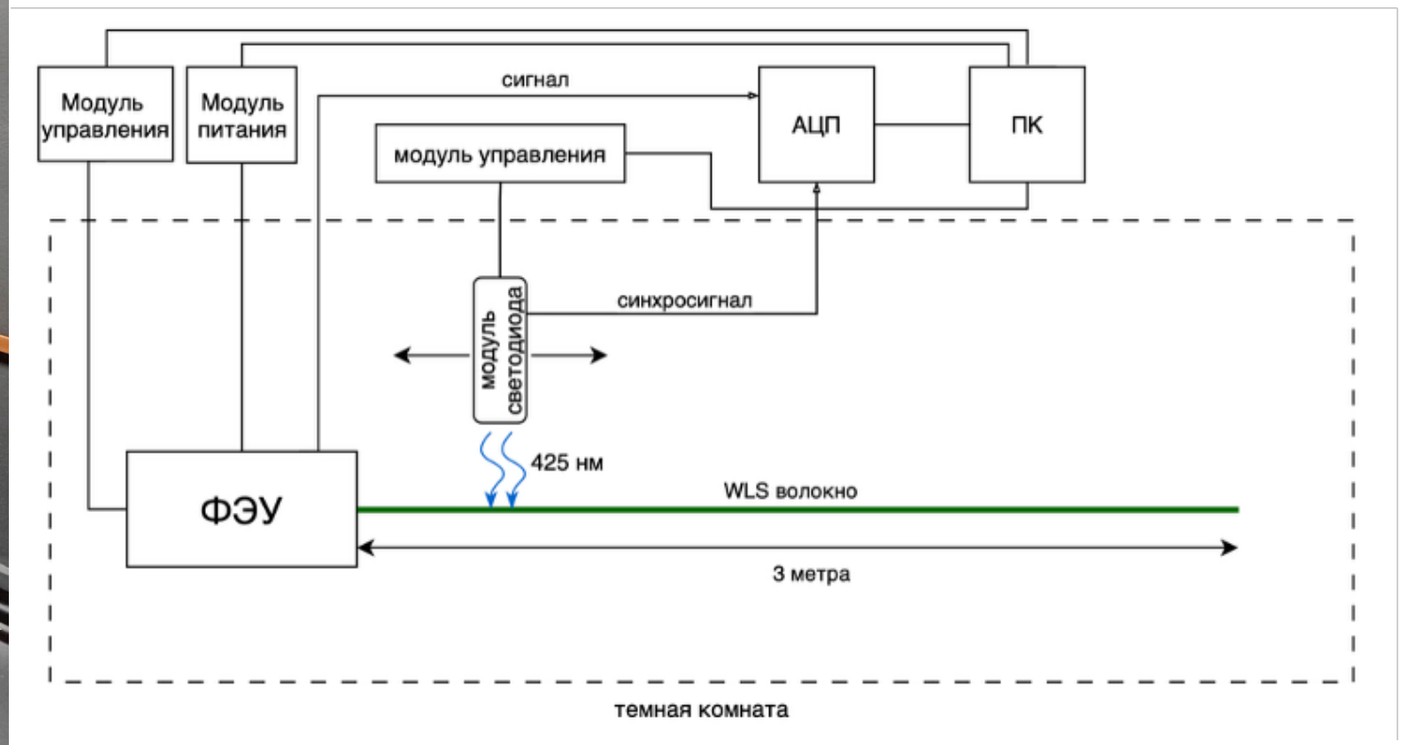




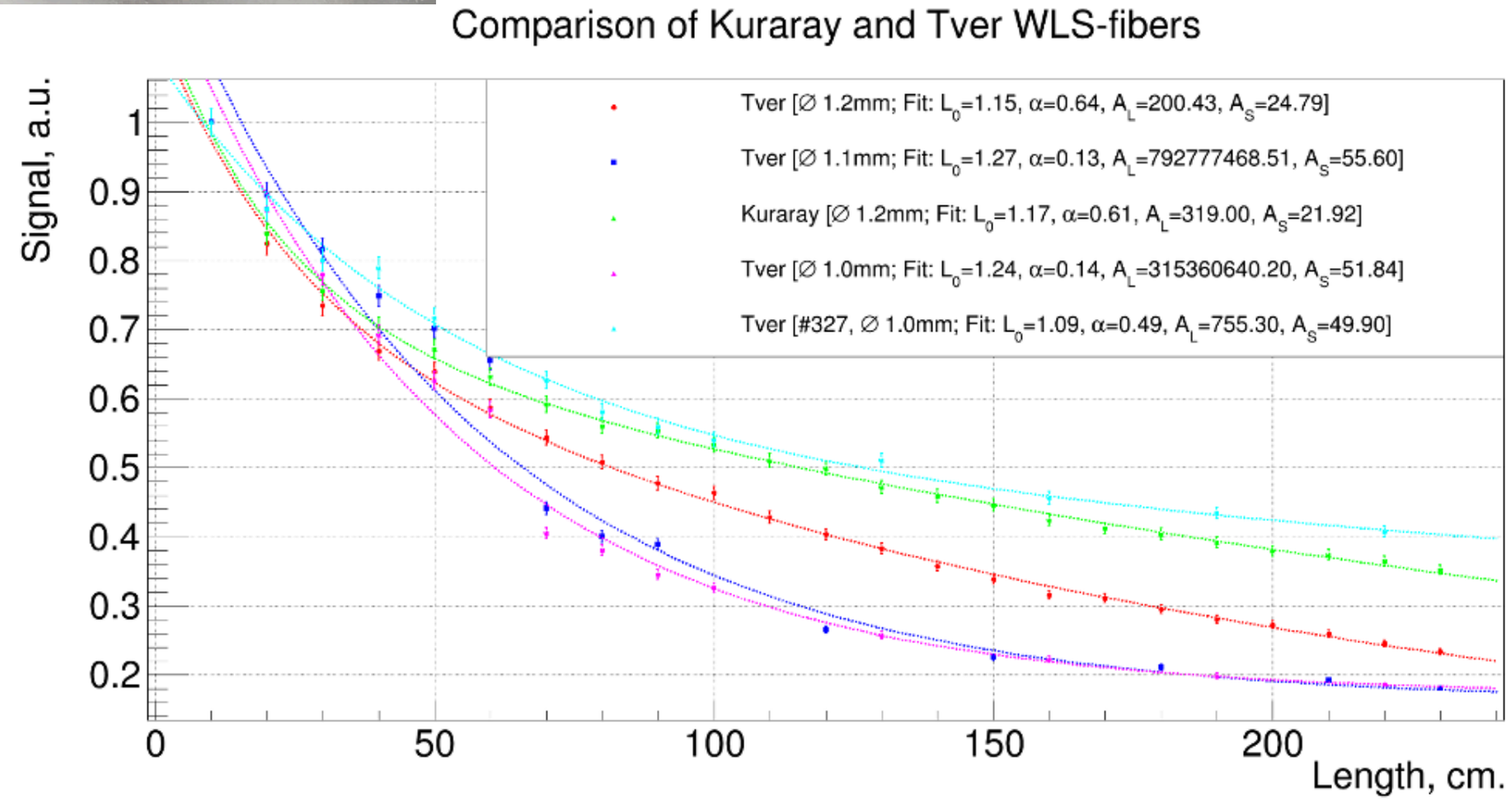


ECAL Fiber study (A. Selyunin, V. Sharov, S. Sokolov))



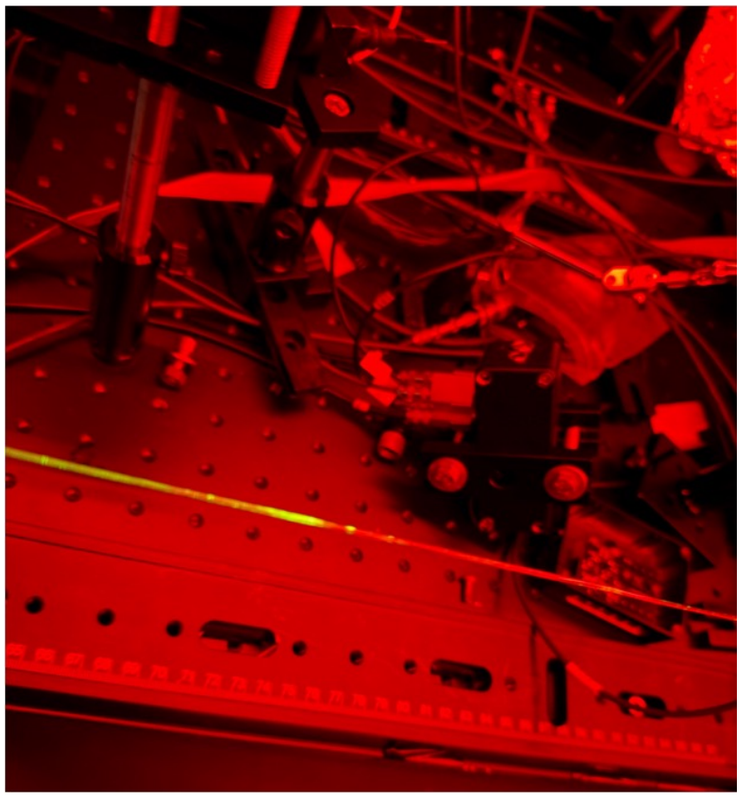






ECAL Fiber study (A. Selyunin, V. Sharov)

1. Полимерное оптическое волокно ТЦ ПОВ, г. Тверь, диаметром 1,2 ± 0,03 мм, № 414: полистирол — 100 %, краситель OSL8 — 0,07 %, оболочка — МПММА.
2. Полимерное оптическое волокно ТЦ ПОВ, г. Тверь, диаметром 1,1 ± 0,03 мм, № 414: полистирол — 100 %, краситель OSL8 — 0,07 %, оболочка — МПММА.
3. Полимерное оптическое волокно ТЦ ПОВ, г. Тверь, диаметром 1,0 ± 0,03 мм, № 323: полистирол — 100 %, краситель OSL8 — 0,1 %, оболочка — МПММА.
4. Полимерное оптическое волокно ТЦ ПОВ, г. Тверь, диаметром 1,0 ± 0,03 мм, № 327: полистирол — 100 %, краситель OSL8 — 0,07 %, оболочка — МПММА.
5. Оптическое волокно Kuraray Y11, контрольное многооболочечное волокно, диаметром 1,2 мм.



Итоги тестирования волокон ТЦ ПОВ (Партия 08.2026)

- **Низкий световыход:** Все образцы уступают контролю (**Kuraray Y11**). Световыход для Ø1,2 мм составляет **42%**, для Ø1,1 мм — **45%**, для Ø1,0 мм — всего **14–20%**.
- **Динамика к I партии:** Качество волокон Ø1,2 мм **выросло**, но у волокон Ø1,0 мм зафиксировано **критическое падение** (ранее было ~70%).
- **Брак и аномалии:** На поверхности обнаружены **дефекты**.

ECAL SiPMs

Type	EQR20 11-3030D-S	EQR20 11-6060D-S
Effective Pitch	20 μm	
Element Number	1×1	
Active Area	3.00×3.00 mm^2	6.24×6.24 mm^2
Micro-cell Number	2500 /mm^2	
Typical Breakdown Voltage (V_B)	27.5 V	
Temperature Coefficient for V_B	24 mV / ℃	
Recommended Operation Voltage	V_B + 5 V	
Peak PDE @ 420nm	46 %	
Gain	8.2×10^5	
Dark Count Rate（DCR）	150 kHz / mm^2	

- 6x6 HPK 13360-6026 PE ~ 100 - 200 $/pc
- 6x6 NDL EQR20 - Huge Cross-talks of 40%

  results: nose rate ~ 1000 cps/ch @ 10 ph.e ~ 30 Mcps total (~5%)

  nose rate ~ 2500 cps/ch @ 9 ph.e ~ 75 Mcps total (~10%)

  nose rate ~ 6500 cps/ch @ 8 ph.e ~ 195 Mcps total (~25%)

- 6x6 NDL EQR15 - affordable solution!

Characterization of the large-size NDL EQR20 silicon photomultipliers

Yu. A. Melikyan [a,1], I.G. Bearden [b], V. Buchakchiev [c], S. Jia [b], V. Kozhuharov [c] and I. P. Møller [b]

[a] *Helsinki Institute of Physics, University of Helsinki, P.O. Box 64, FI-00014, Finland*
[b] *Niels Bohr Institute, University of Copenhagen, Jagtvej 155A, 2200 Copenhagen, Denmark*
[c] *Faculty of Physics, Sofia University "St.Kliment Ohridski", 5 J. Bourchier Blvd, 1164 Sofia, Bulgaria*

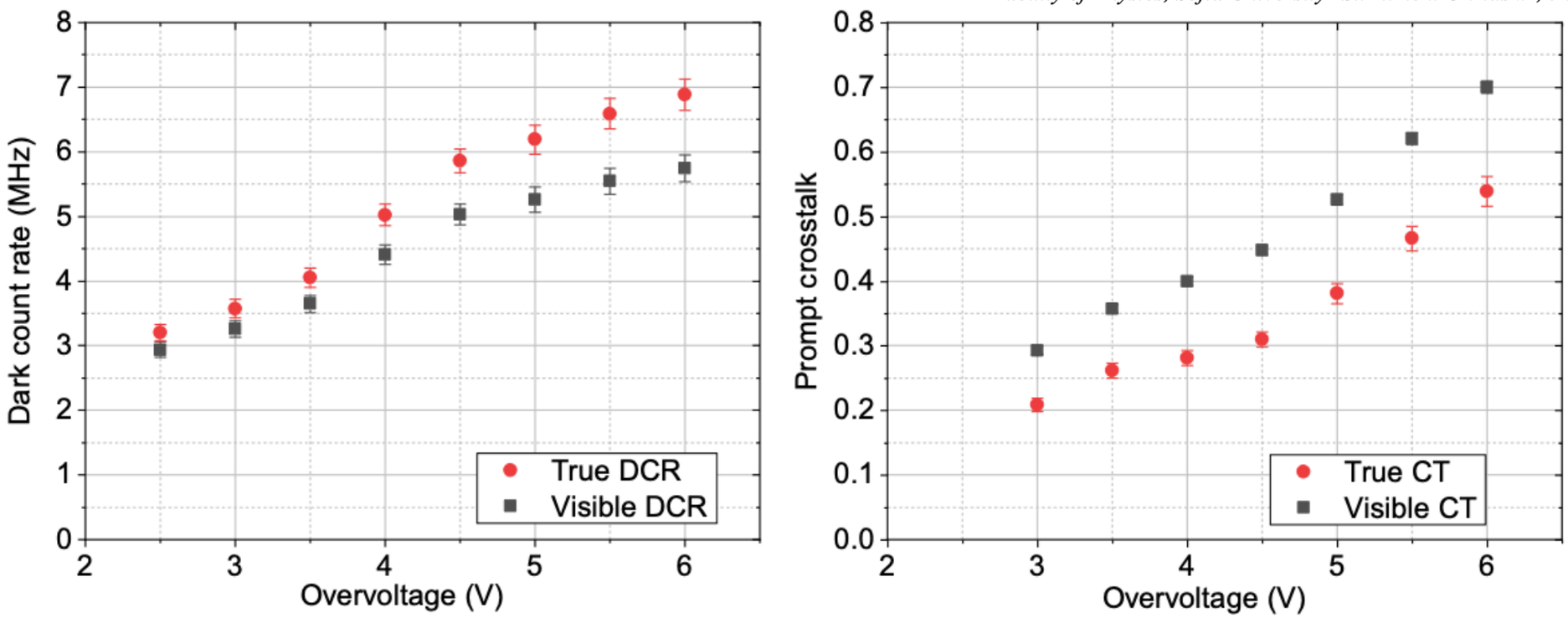


Figure 11. Dark count rate and prompt crosstalk measured at 25°C as a function of the overvoltage of the NDL EQR20 11-6060D-S SiPM sized 6.24x6.24 mm^2.

ECAL SiPMs

Characterization of the large-size NDL EQR20 silicon photomultipliers

Yu. A. Melikyan [a,1], I.G. Bearden [b], V. Buchakchiev [c], S. Jia [b], V. Kozhuharov [c] and I. P. Møller [b]

[a] *Helsinki Institute of Physics, University of Helsinki, P.O. Box 64, FI-00014, Finland*
[b] *Niels Bohr Institute, University of Copenhagen, Jagtvej 155A, 2200 Copenhagen, Denmark*
[c] *Faculty of Physics, Sofia University "St.Kliment Ohridski", 5 J. Bourchier Blvd, 1164 Sofia, Bulgaria*

- **Huge Amplitude Non-linearity.**
- **Solutions: Long-Shaping or Integration**

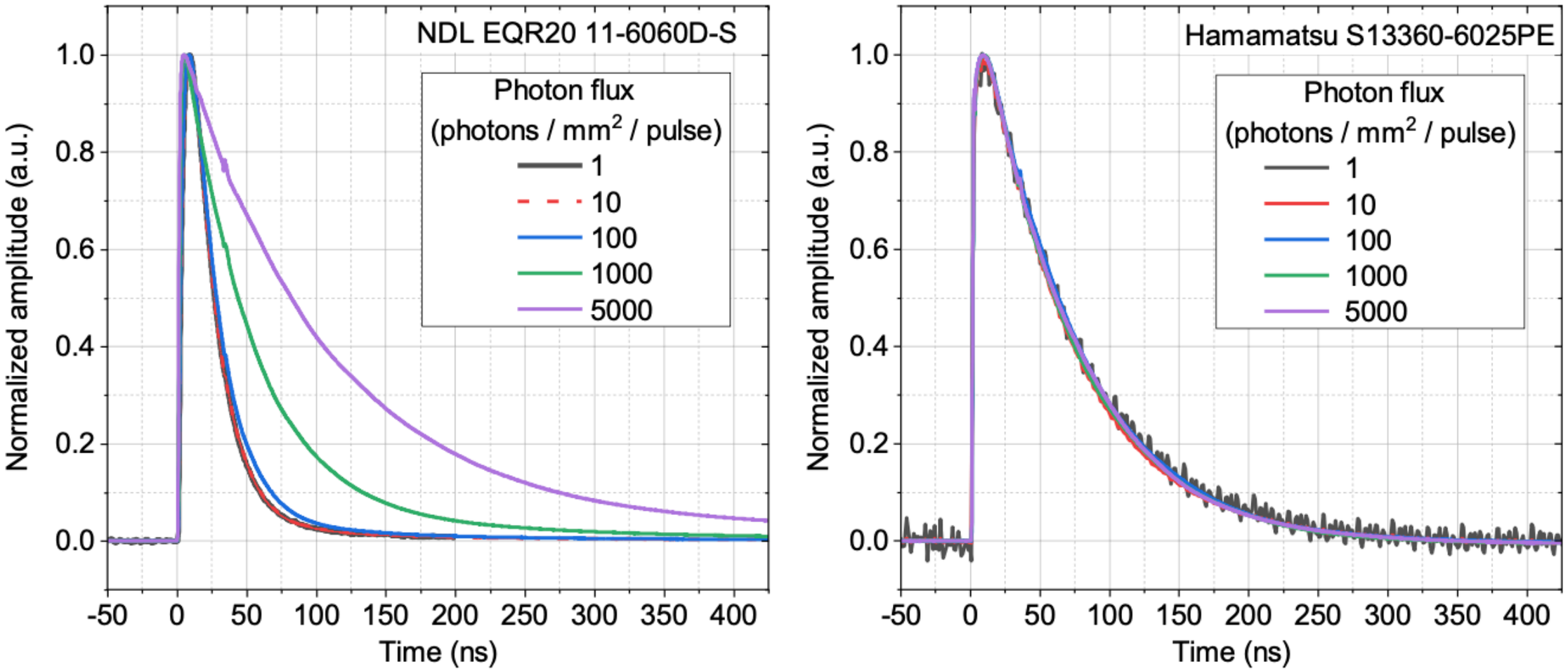
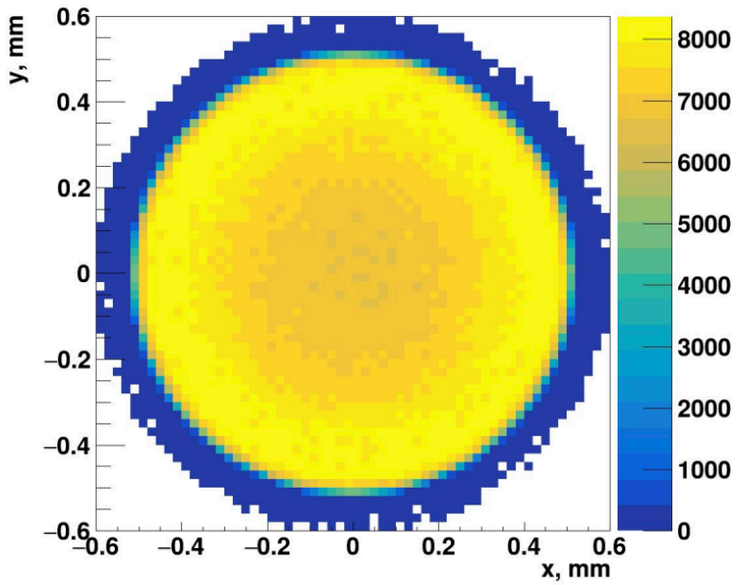


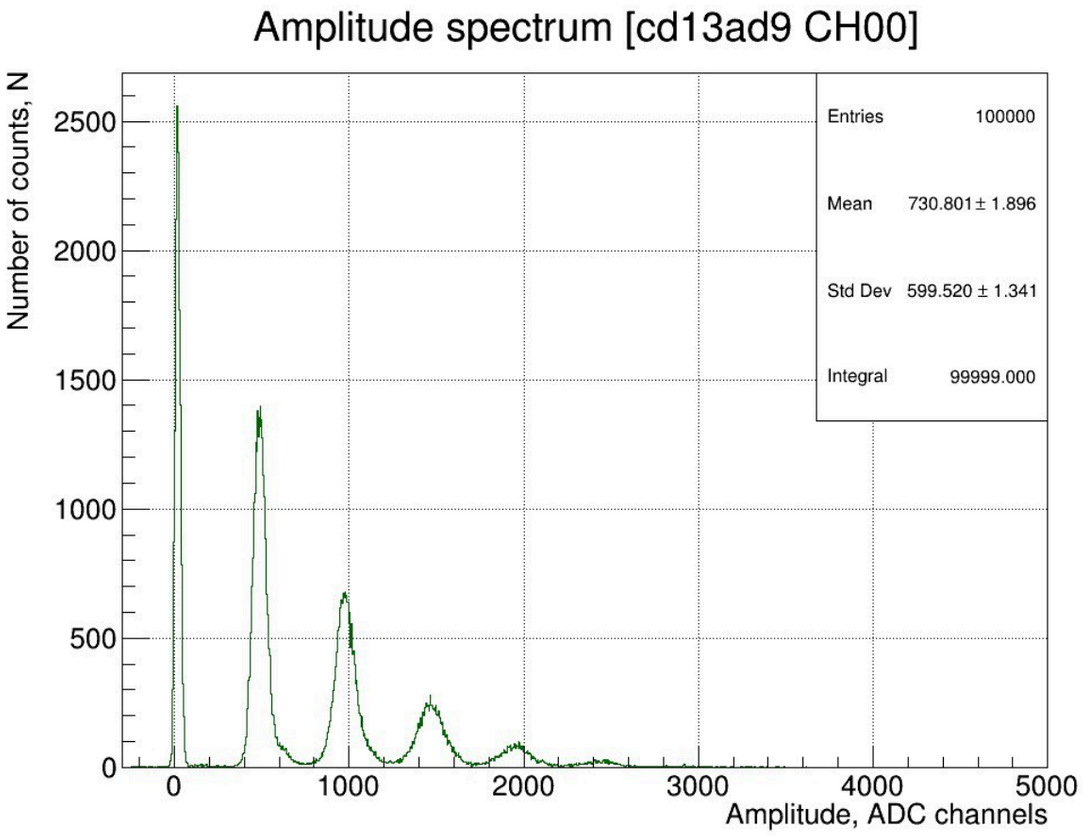
Figure 14. Waveforms of SiPM signals under picosecond laser illumination of various intensity.

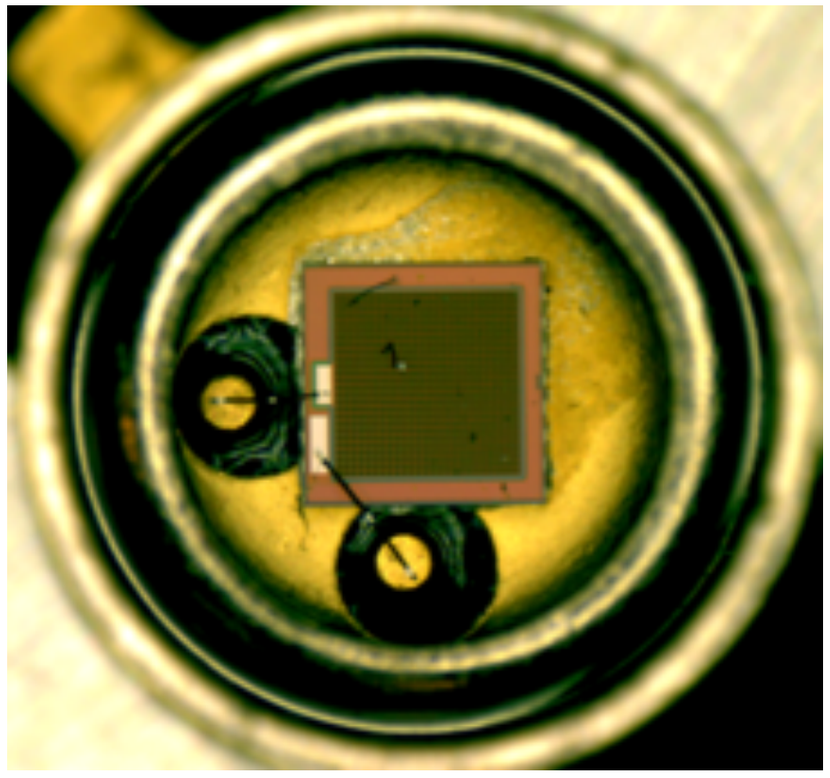
ECAL SiPMs
(A. Selyunin, V. Sharov, A. Solin, N. Zamyatin)

- 1.3x1.3 mm^2 SiPM matches individual fiber.
- «Integral» SiPM 1.3x1.3 is available:
  - 25, 50 um pixel pitch - 13-25, 13-50
  - noise rate ~ 100 kcps
  - cross-talk < 5%
  - PDE - (p-Si, 650 nm) ?
- «Integral» SiPM 3.0x3.0 is also available:
  - 3-15F, 3-35F, 3-50F, 3-20F

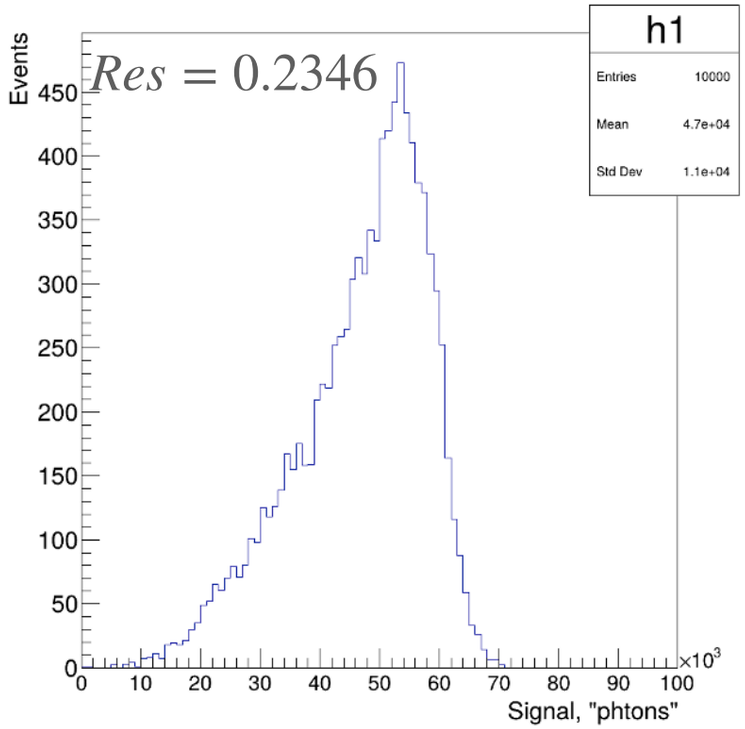


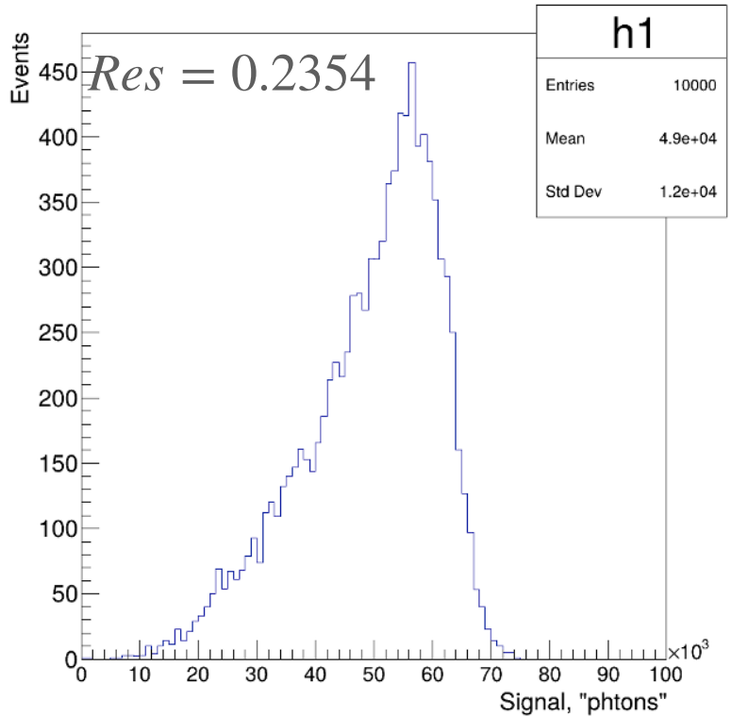
Distribution of the photons at the end of the WSL fiber (simulation)

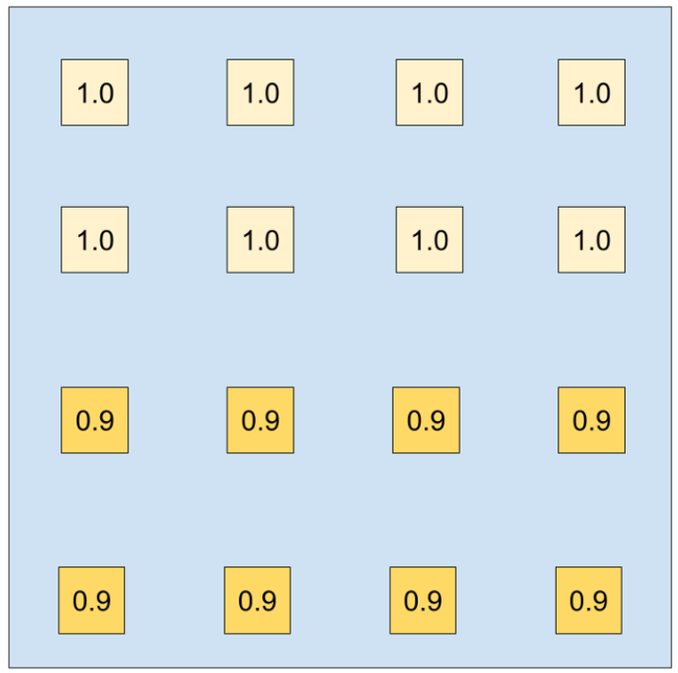


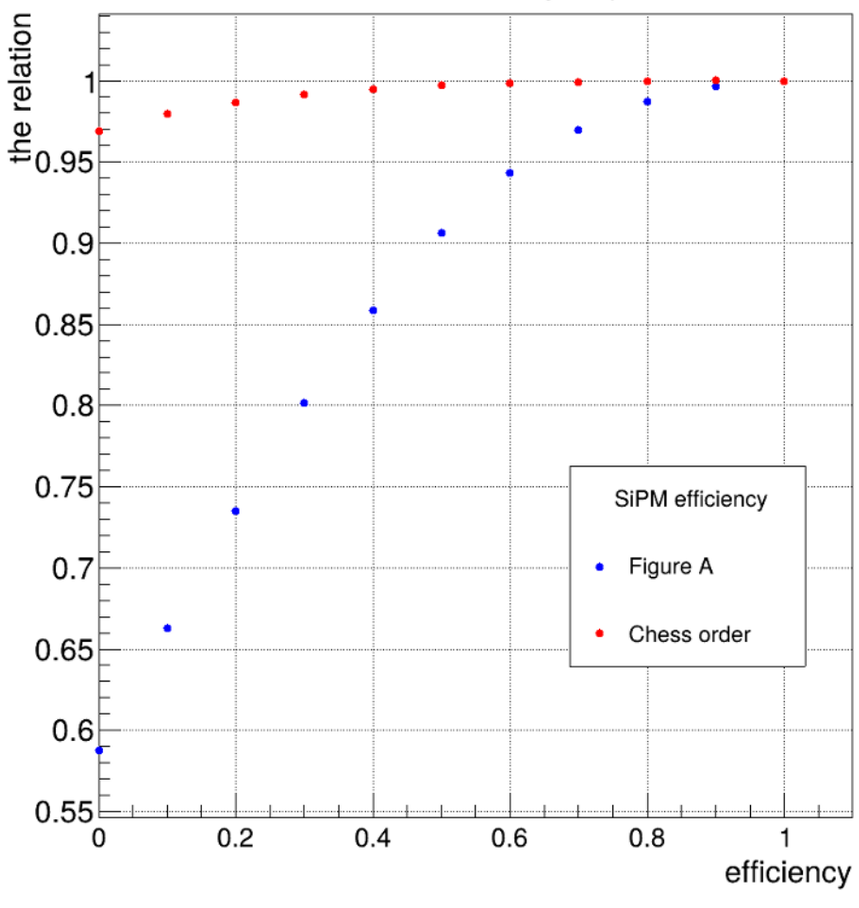


ECAL Individual Fibers simulation (I. Zimin)







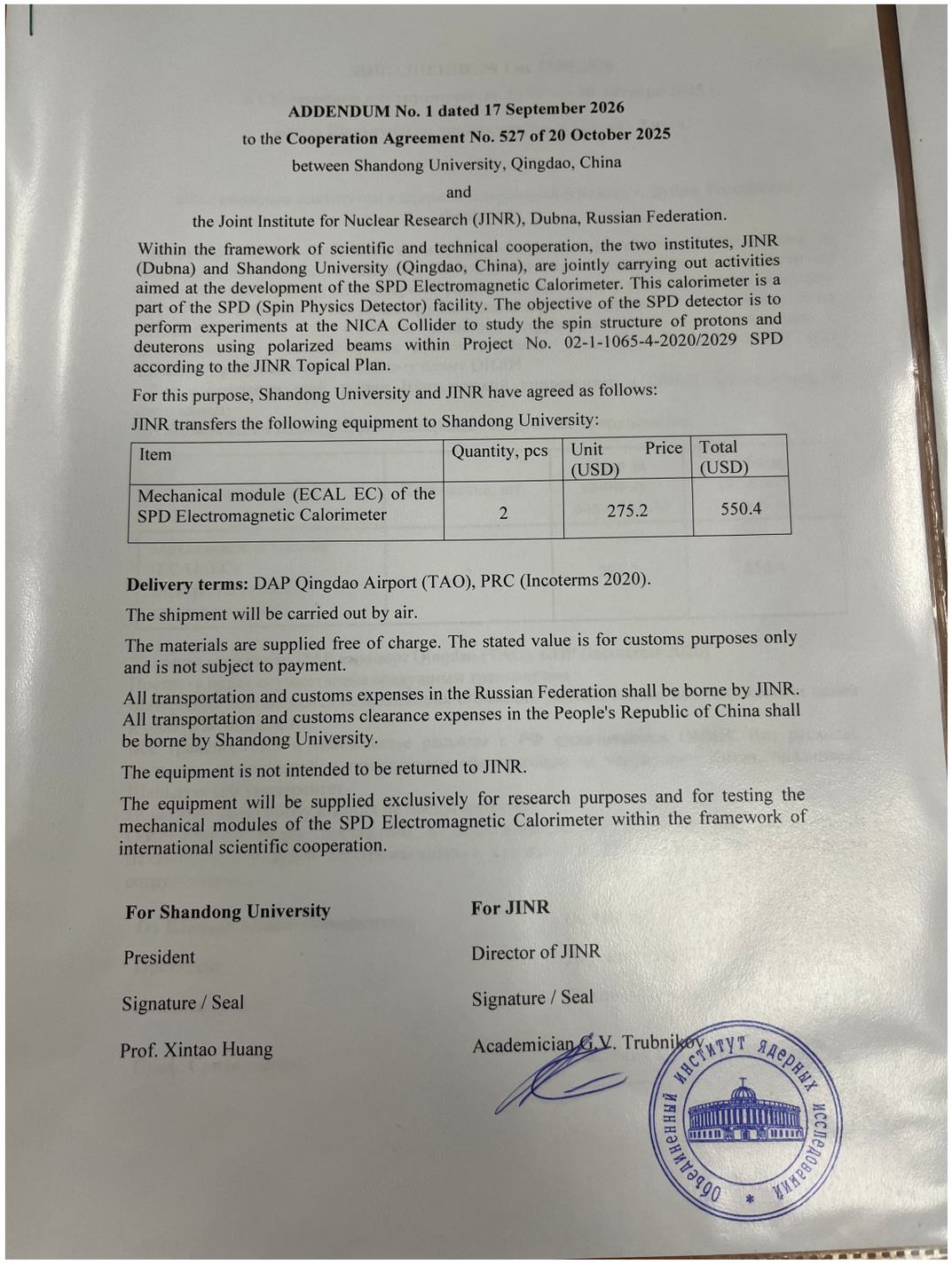


A random distribution of SiPMs can tolerate a PDE variation of ~30%.

Compatible with standard «Integral» Technology fabrication processes.

International cooperation

Shipment (K. Kuznetsova)



ADDENDUM No. 1 dated 17 September 2026

to the **Cooperation Agreement No. 527 of 20 October 2025**

between Shandong University, Qingdao, China

and

the Joint Institute for Nuclear Research (JINR), Dubna, Russian Federation.

Within the framework of scientific and technical cooperation, the two institutes, JINR (Dubna) and Shandong University (Qingdao, China), are jointly carrying out activities aimed at the development of the SPD Electromagnetic Calorimeter. This calorimeter is a part of the SPD (Spin Physics Detector) facility. The objective of the SPD detector is to perform experiments at the NICA Collider to study the spin structure of protons and deuterons using polarized beams within Project No. 02-1-1065-4-2020/2029 SPD according to the JINR Topical Plan.

For this purpose, Shandong University and JINR have agreed as follows:

JINR transfers the following equipment to Shandong University:

Item	Quantity, pcs	Unit Price (USD)	Total (USD)
Mechanical module (ECAL EC) of the SPD Electromagnetic Calorimeter	2	275.2	550.4

Delivery terms: DAP Qingdao Airport (TAO), PRC (Incoterms 2020).

The shipment will be carried out by air.

The materials are supplied free of charge. The stated value is for customs purposes only and is not subject to payment.

All transportation and customs expenses in the Russian Federation shall be borne by JINR. All transportation and customs clearance expenses in the People's Republic of China shall be borne by Shandong University.

The equipment is not intended to be returned to JINR.

The equipment will be supplied exclusively for research purposes and for testing the mechanical modules of the SPD Electromagnetic Calorimeter within the framework of international scientific cooperation.

For Shandong University

President

Signature / Seal

Prof. Xintao Huang

For JINR

Director of JINR

Signature / Seal

Academician G.V. Trubnikov

Объединенный институт ядерных исследований

The document is ready to be signed by the Chinese side.

We will dispatch it to China via DHL for prompt signing.

Summary

A test stand will be operated at DLNP for cross-checking and future QA/QC processes.

Electronics development is ongoing; we need to decide on the implementation of low- and high-gain capabilities to calibrate and operate the ECAL.

The low sensitivity of the energy resolution to the PDE distribution enables the easy implementation of an individual SiPM readout and allows us to shorten the barrel module by 4–5 cm (1–2 radiation lengths).

We are preparing two modules for shipment once the documents are signed.