3D сегментированный сцинтилляционный детектор нейтрино для осцилляционных экспериментов

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Ученый совет ИЯИ РАН
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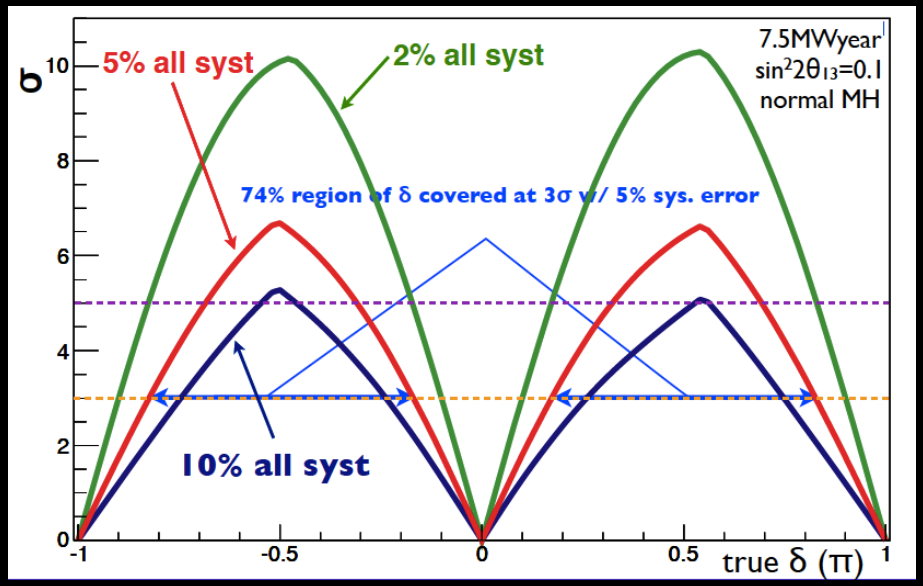
Physics motivation

HyperK, 750 kW -10 years, 1.3 kW – 6 years



LBL oscillation experiments
T2K-II, T2HK, DUNE
Search for CP violation, MH measurement
$\nu_\mu \rightarrow \nu_e$ 10^3 – 10^4 events

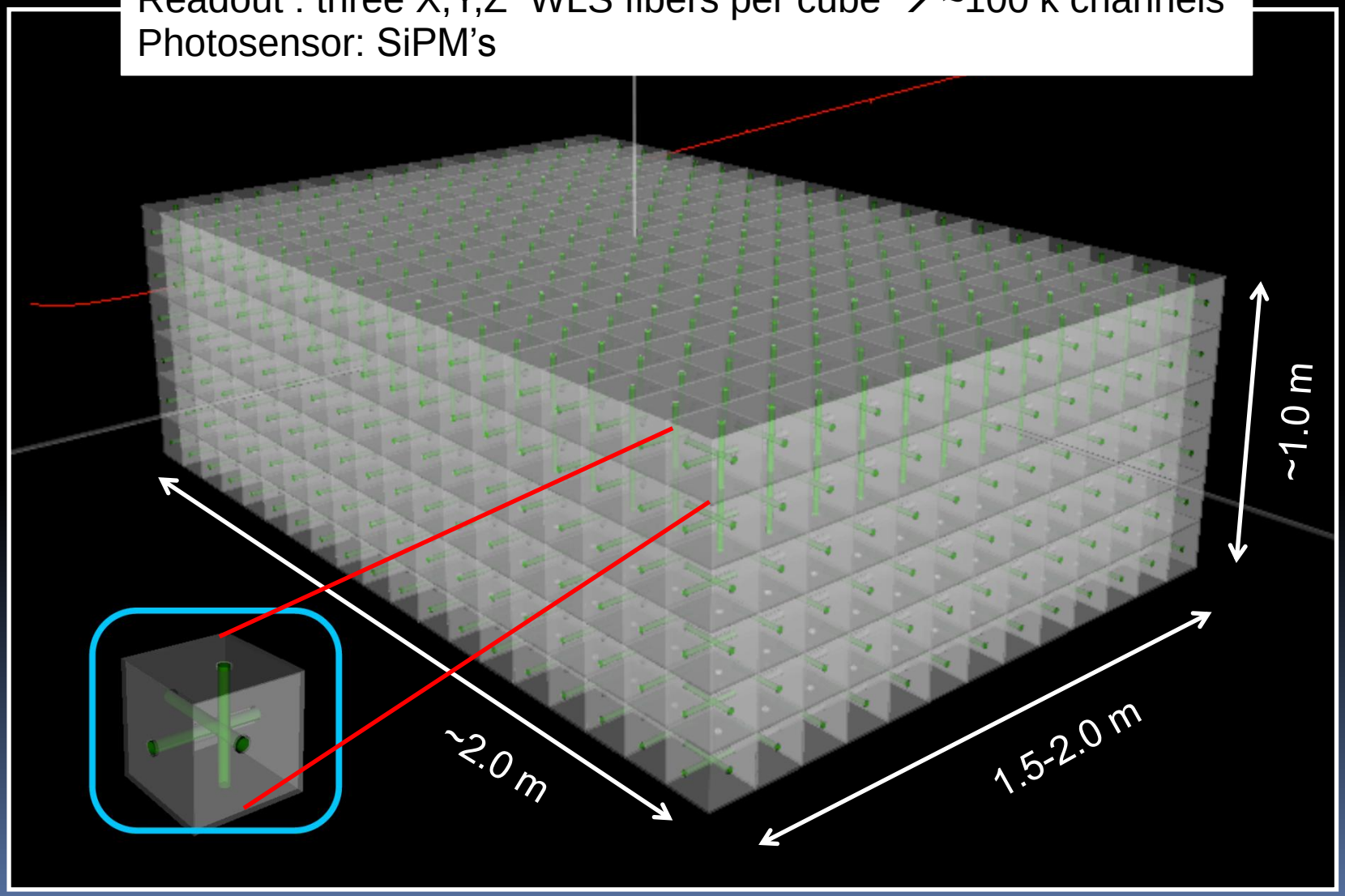
Issues:

→ systematic uncertainties ≤ 2%
→ anti-nu cross sections
→ $\sigma(\nu e)/\sigma(\nu\mu)$ < 2%
→ CCQE 4π high acceptance
→ ν CC low threshold of protons ~45 MeV, cross sections, nuclear models
→ e/gamma separation

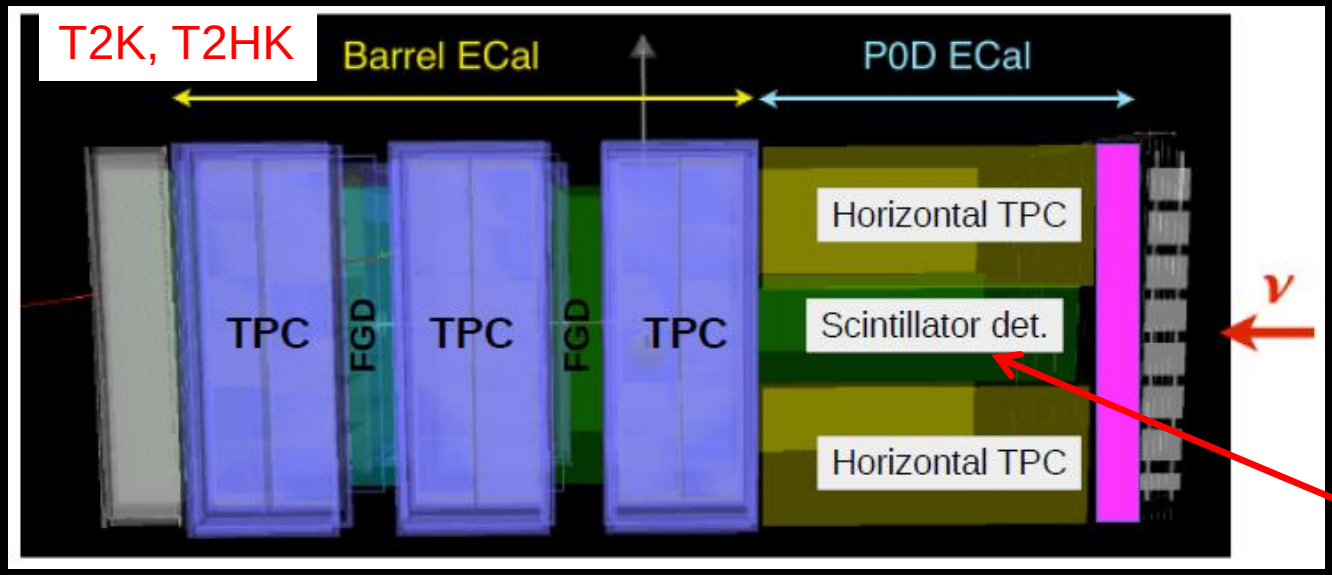
Relatively small detector of reactor antineutrinos
- 4π uniform detector
- positron detection with high spatial and energy resolution direction of positrons from anti-nu interactions
- efficient neutron detection

3D neutrino target/detector

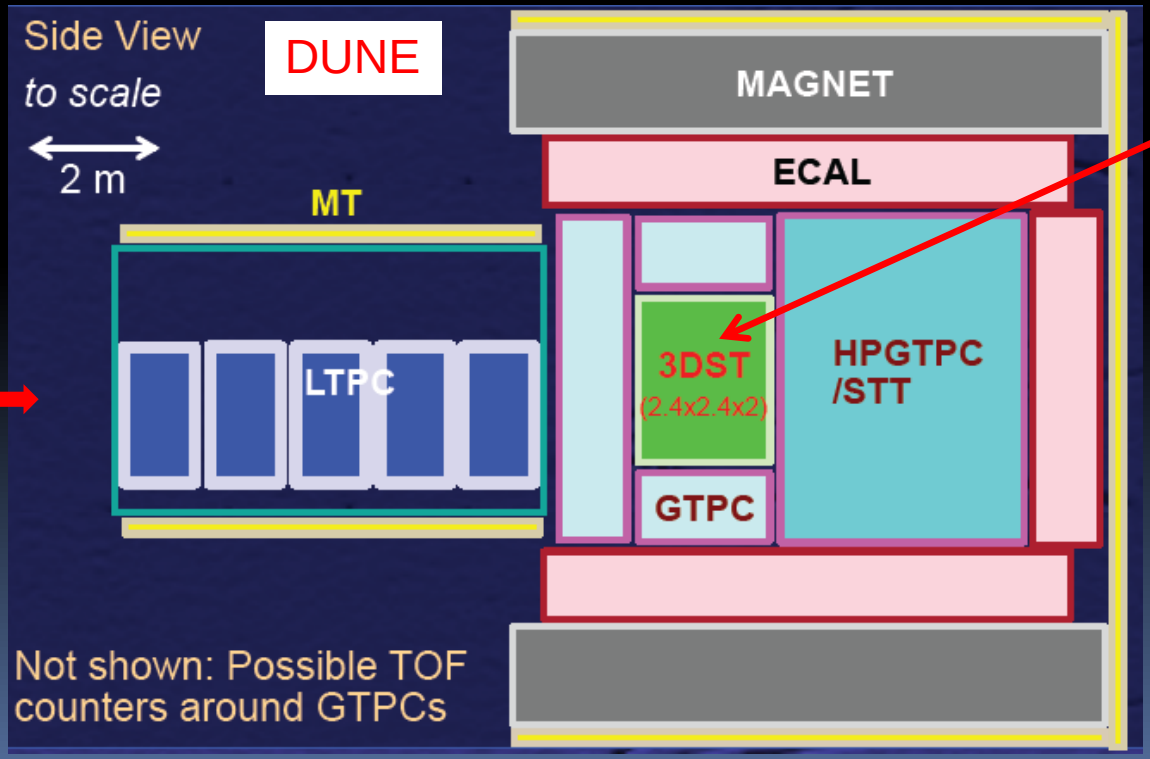
3D Segmented Scintillator neutrino Detector (3D SSD)
Mass ~ few tons
Scintillator cubes 1cm^3 $\geq 10^6$
Readout : three X,Y,Z WLS fibers per cube → ~100 k channels
Photosensor: SiPM's



Intergration in near detectors



Possible integration of 3D segmented detector in ND complex

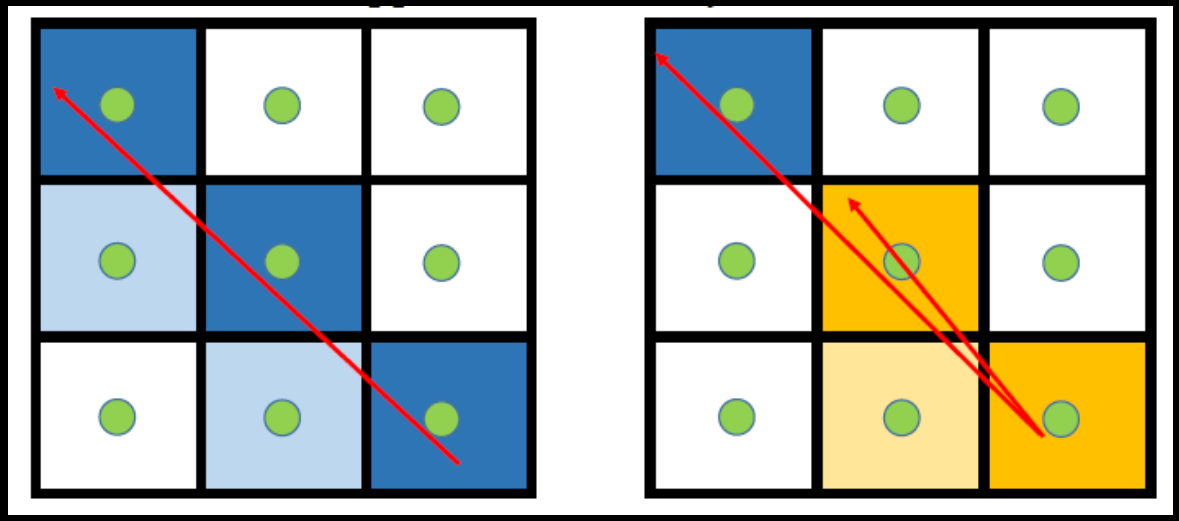


3D segmented detector

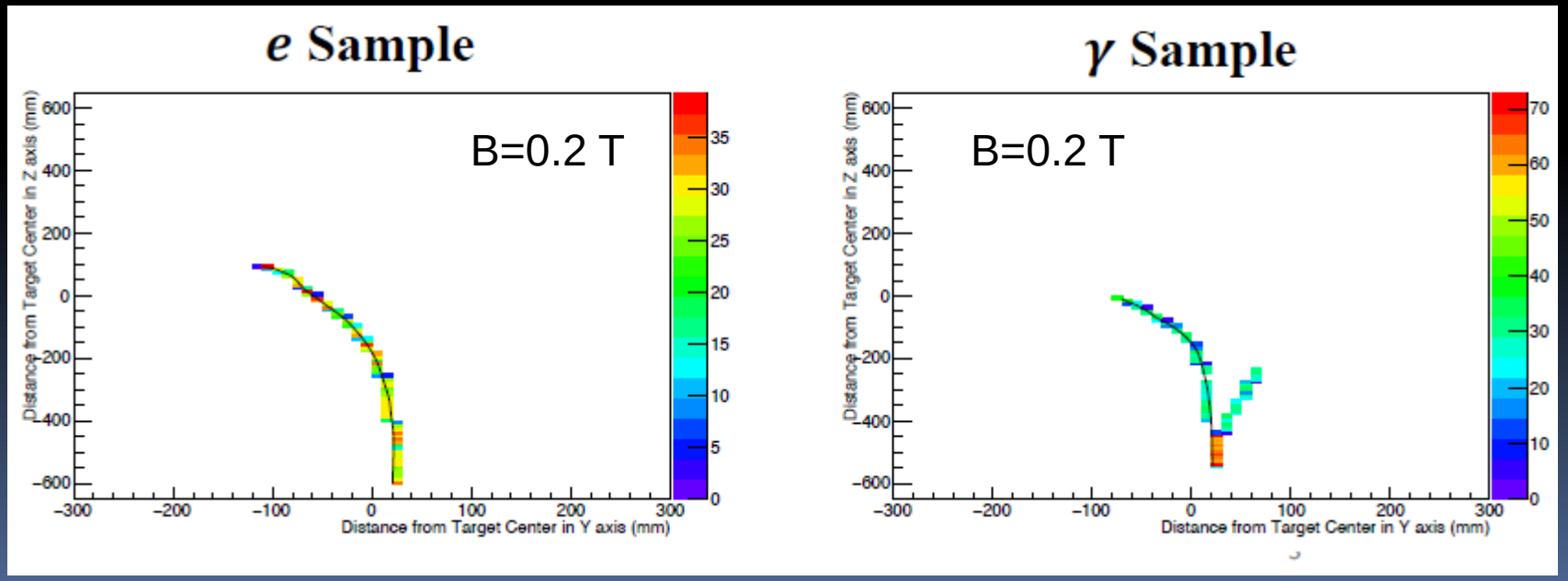
e/γ separation

Monte Carlo simulations

e



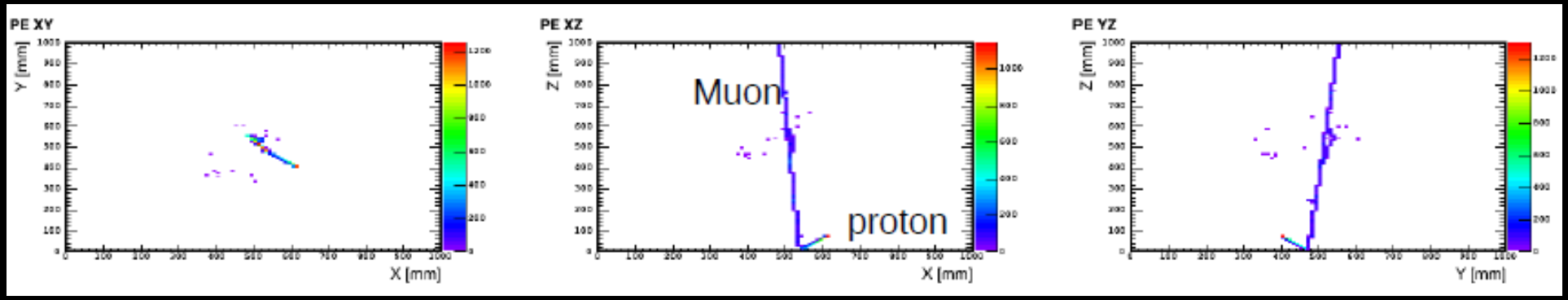
γ



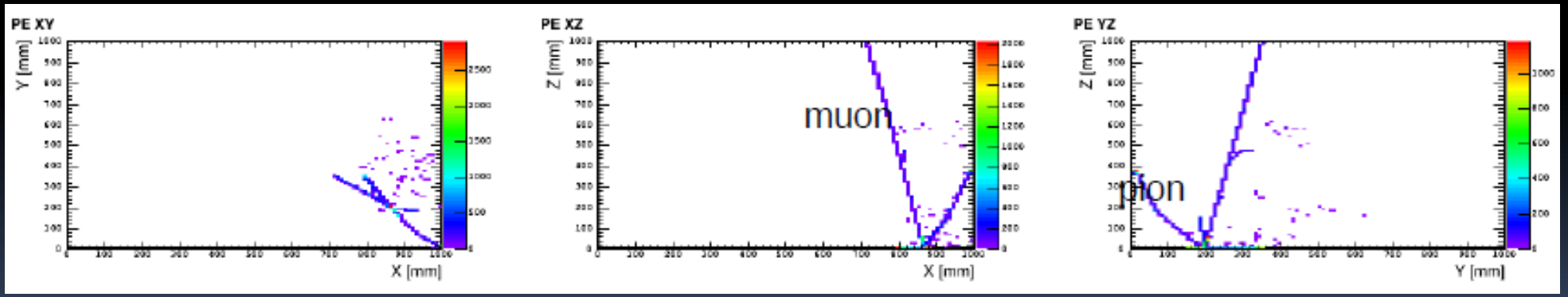
ν interactions

Monte Carlo simulations

CCQE



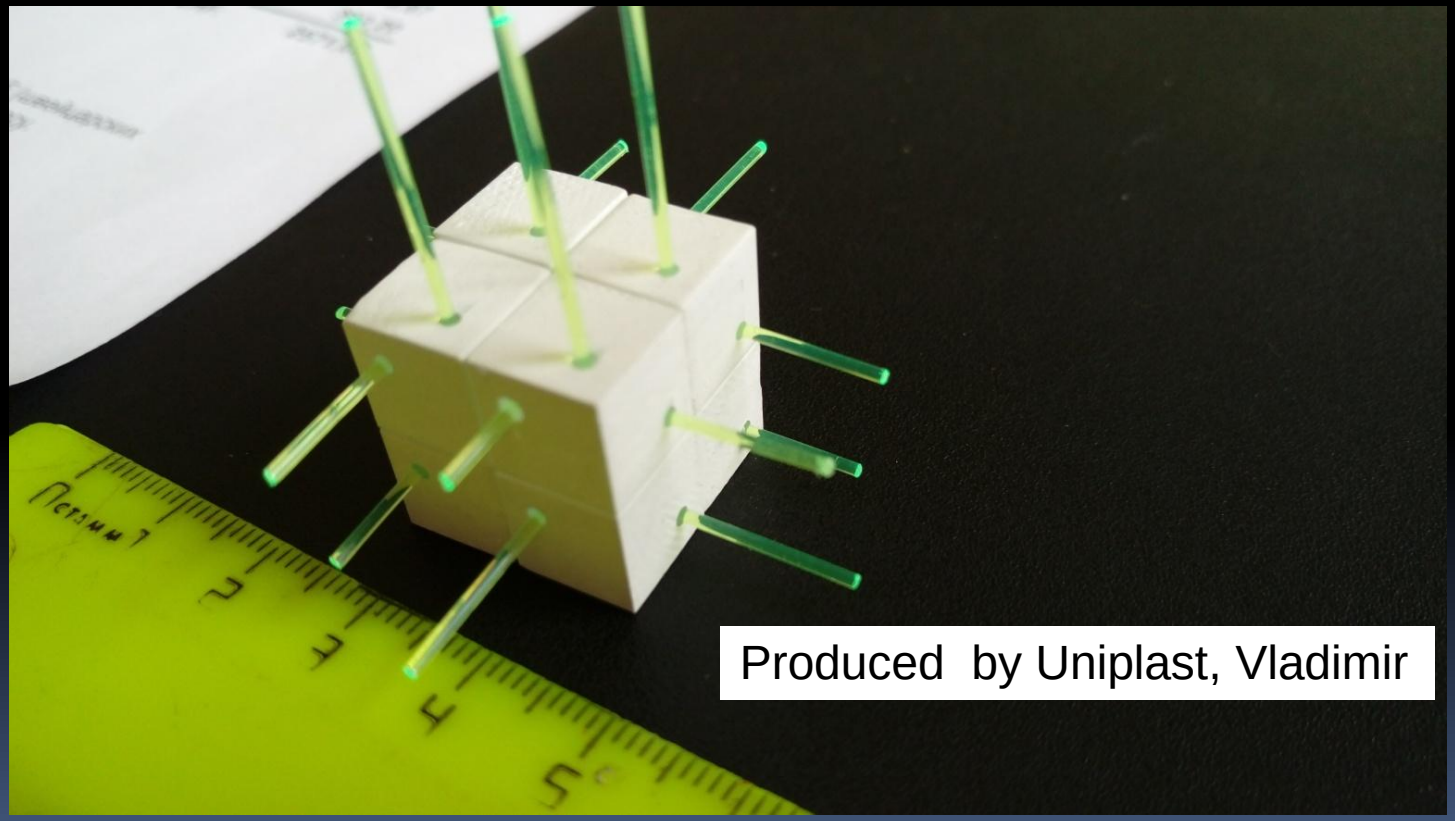
CC1π



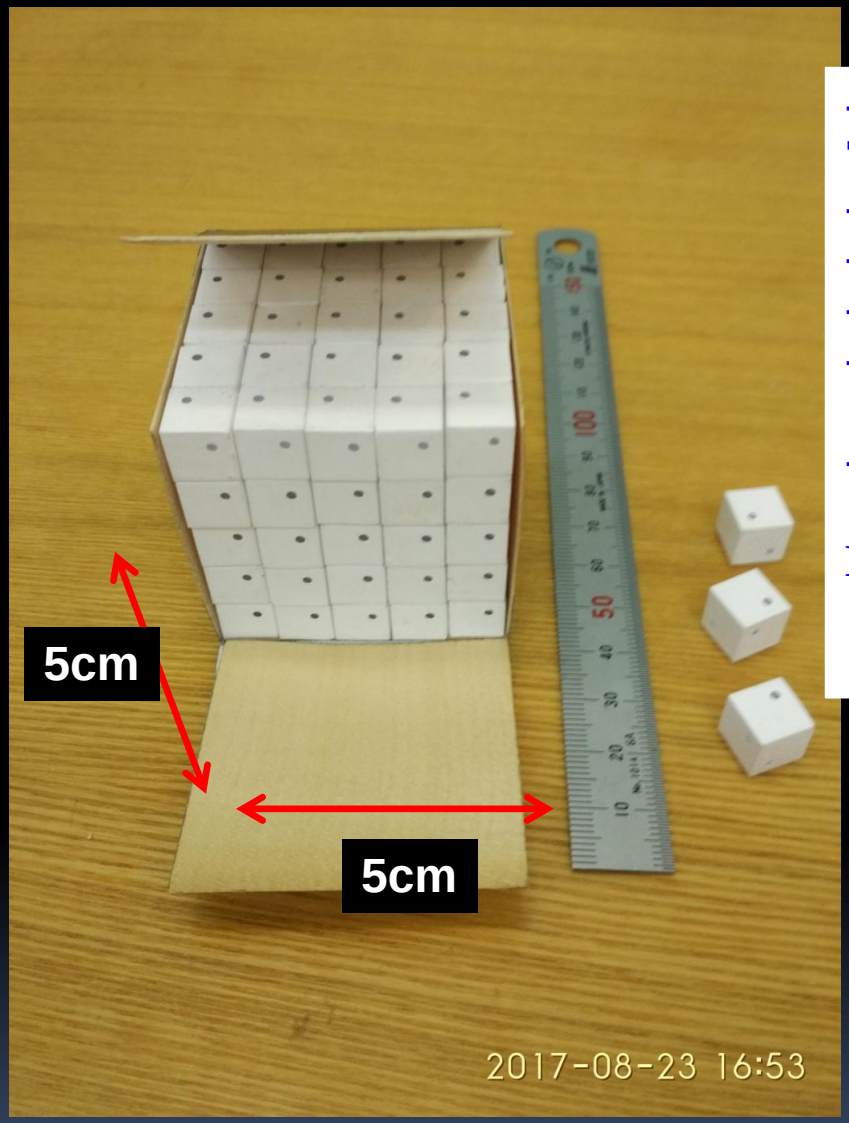
Scintillator cubes

ArXiv:1707.01785

Cubes: 10x10x10 mm^3
Material: extruded polystyrene + p-terphenyl
White chemical reflector, thickness ~ 50 mkm
3 holes: each of 1.5 mm diameter
WLS fibers: Kuraray Y11, double clad 1.0 mm diameter



Prototype for test at CERN



- 125 cubes of 1 cm^3 were tested
75 WLS fibers with 75 SiPM readout → 75 readout channels
- Length of Kuraray 1 mm Y11 WLS fibers 130 cm
- 3 fibers inserted in one cube, no glue
- Distance between MPPC and cube in each fiber 100 cm
- Reflector at far end of the fiber - white paint Silver Shine

- Trigger counters 3x3 mm^2

MPPC :
S12571-025C, pixel size 25 microns,
PDE about 33% for green light.

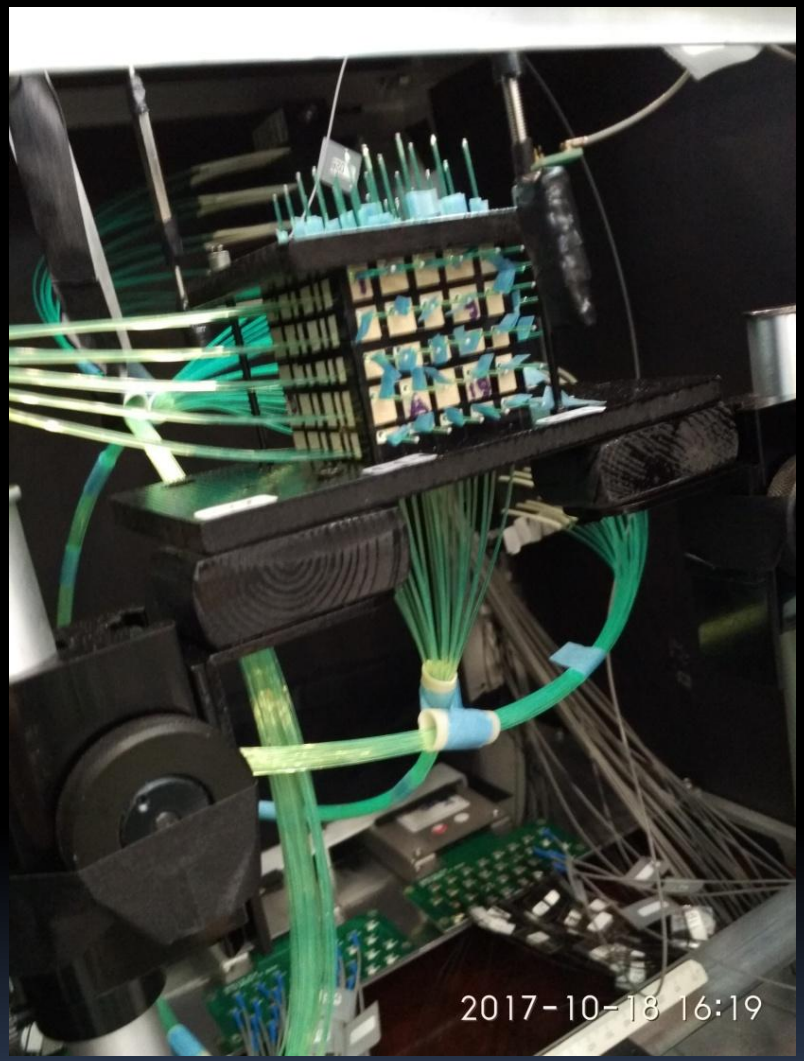
Electronics

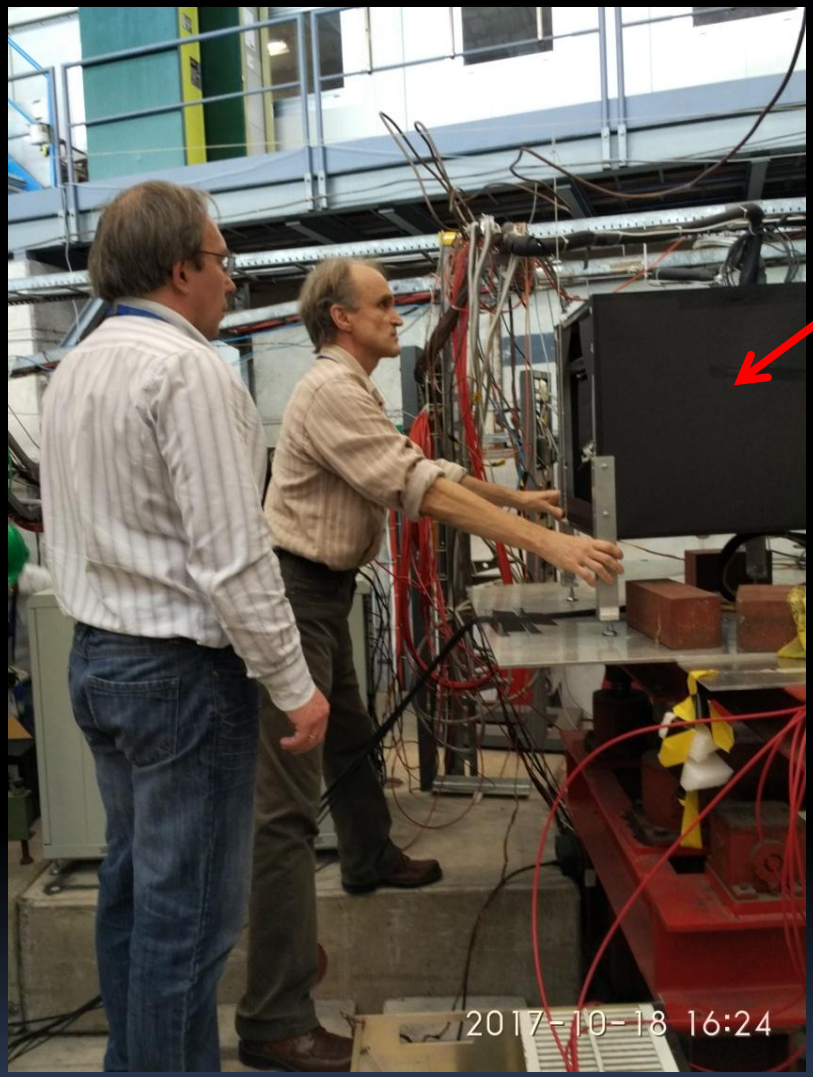
- Amplitude 75 ADC channels CITIROC ASICs (from Baby-MIND)
-Timing and amplitude 15 channels, digitizer CAEN DT5742 5 GHz

T10 area at CERN

Beam test at T10 (CERN) : 28 October - 1 November 2017
p (π, μ) = 6 GeV/c
Beam spot ~3 cm (horiz)x 6 cm (vert)
Trigger counters (in front/behind prototype) 3 x 3 mm2
Veto counter : beam hole 9 mm diameter

Installation at T10

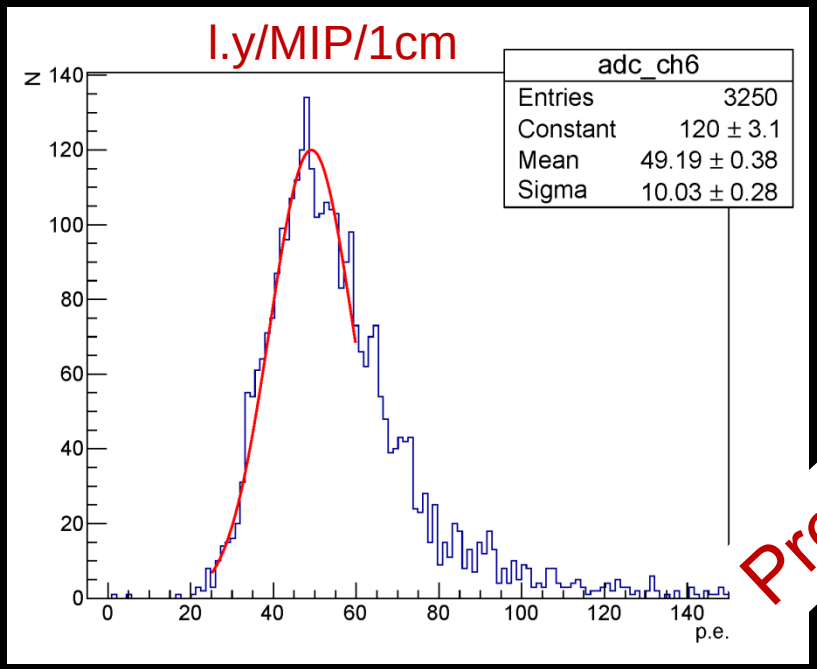


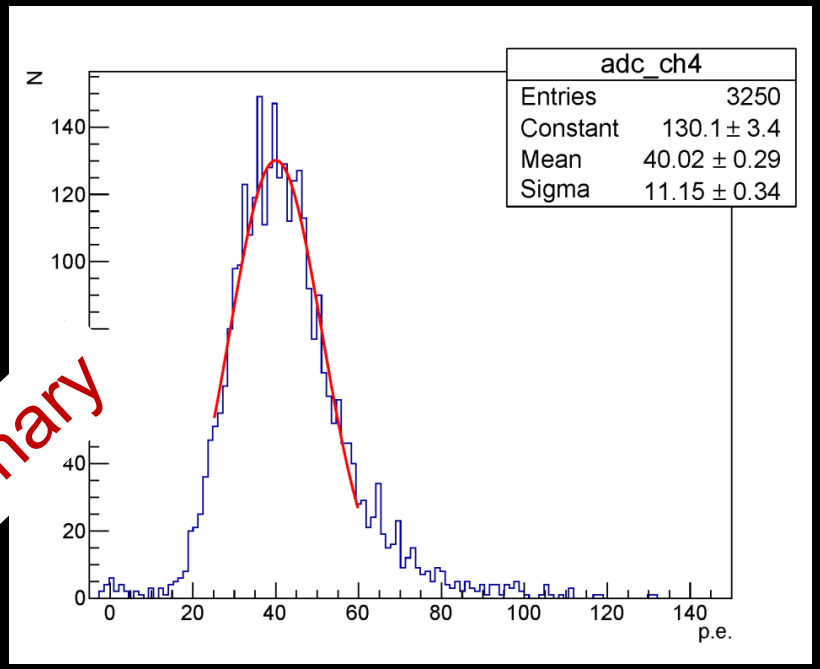


Detector

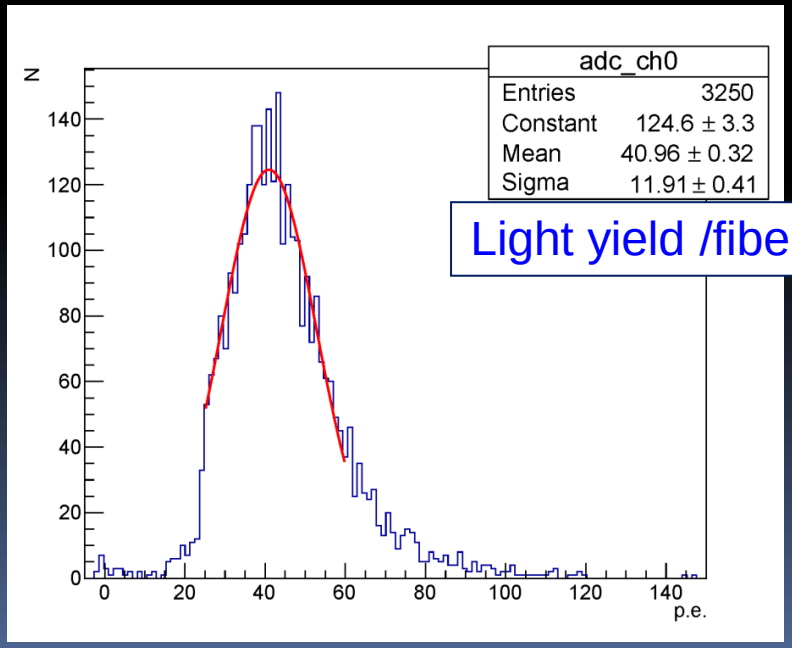
Light Yield (1)

Digitizer CAEN DT5742

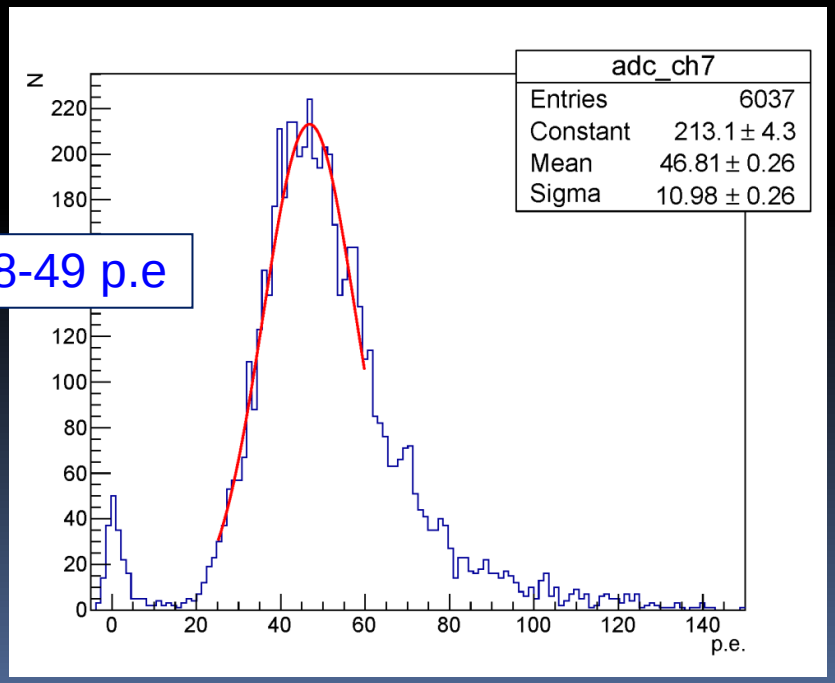




Preliminary

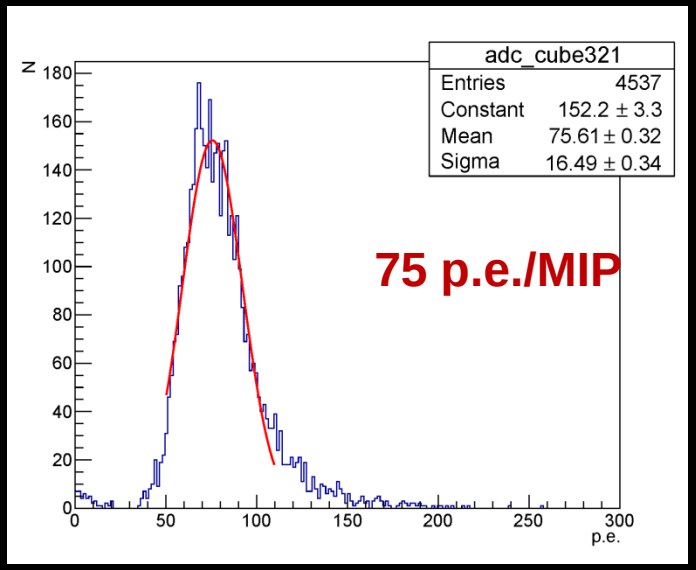


Light yield /fiber ~ 38-49 p.e

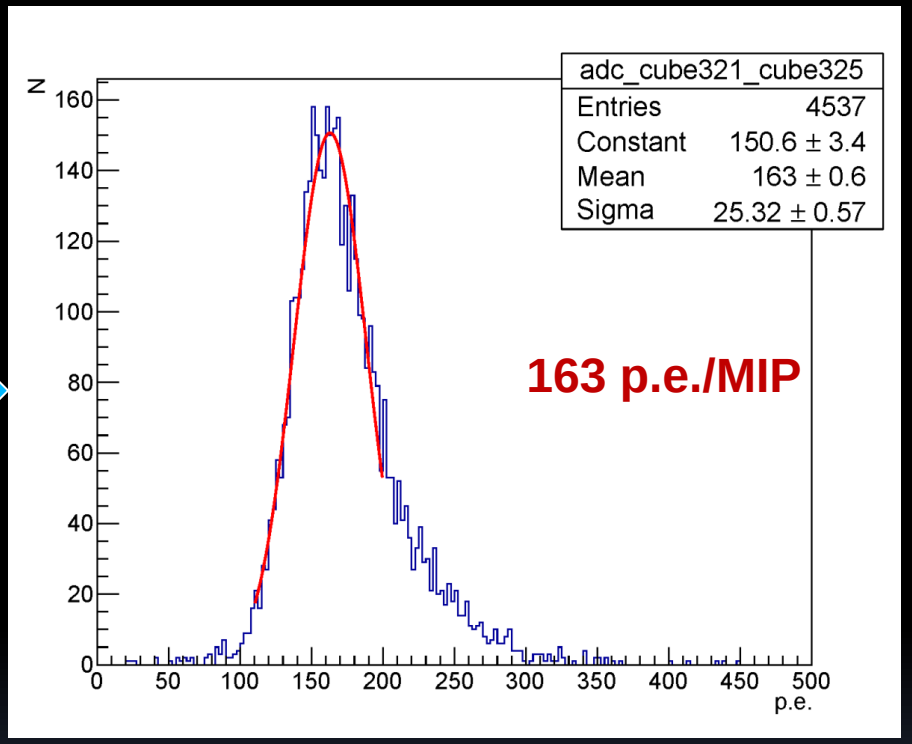


Light Yield (2)

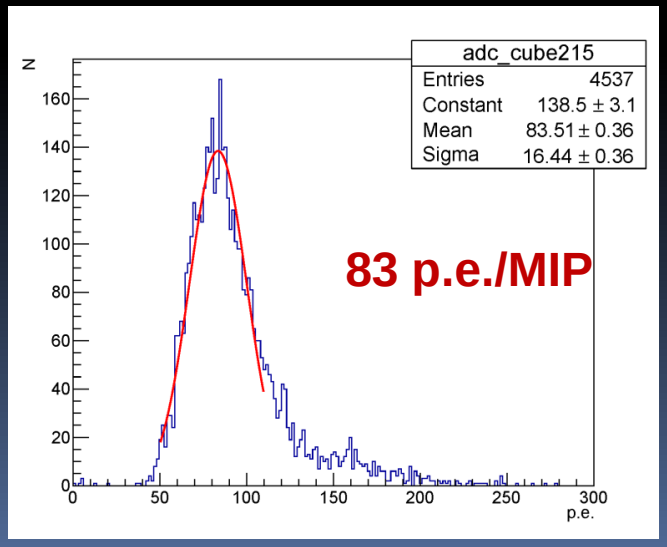
1 cube – readout sum of 2 fibers



Sum of 2 cubes, readout sum of 4 fibers



1 cube – readout sum of 2 fibers

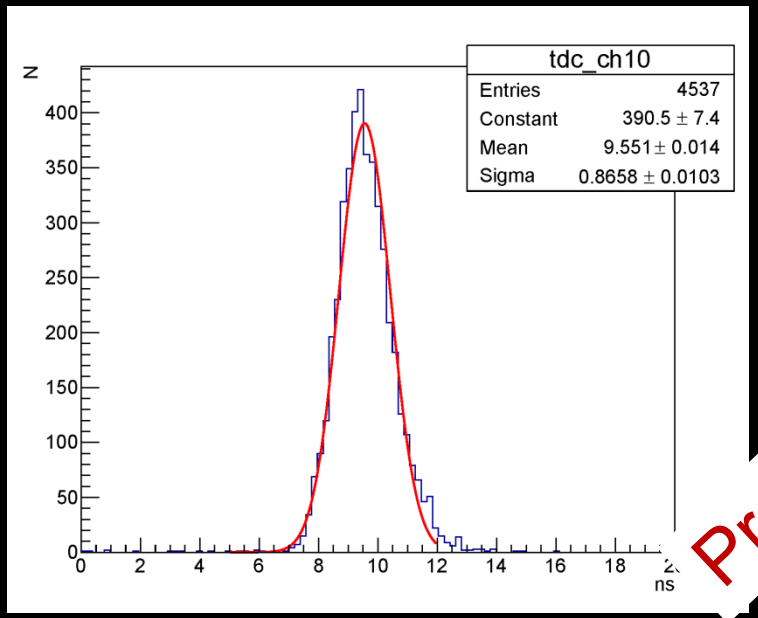


L.Y. ~ number of readout fibers of fired cubes

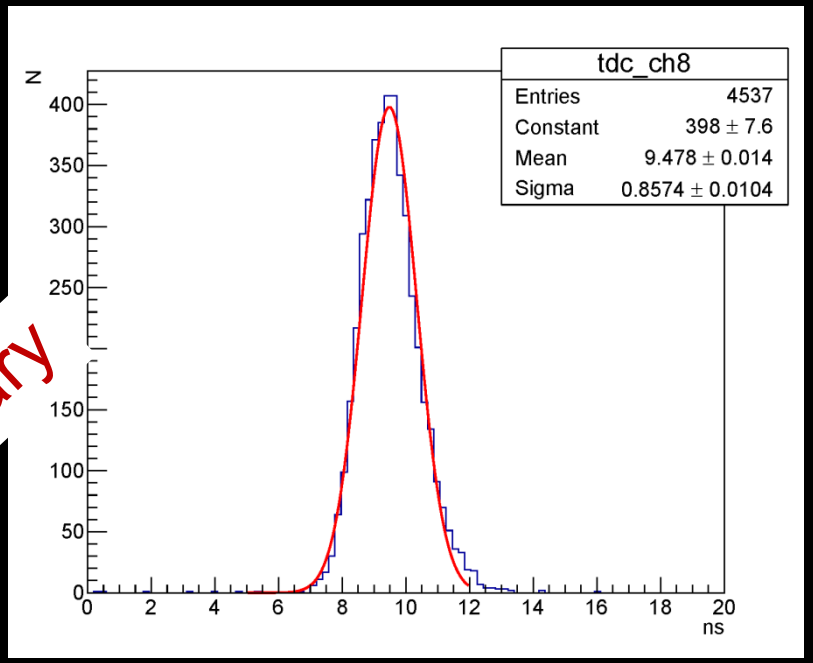
Timing (1)

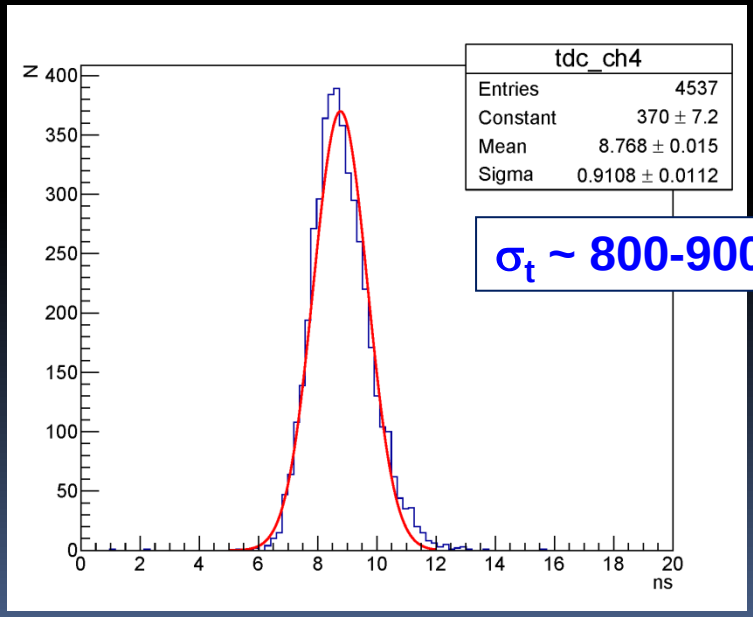
Digitizer CAEN DT5742

Signal from 1 fiber

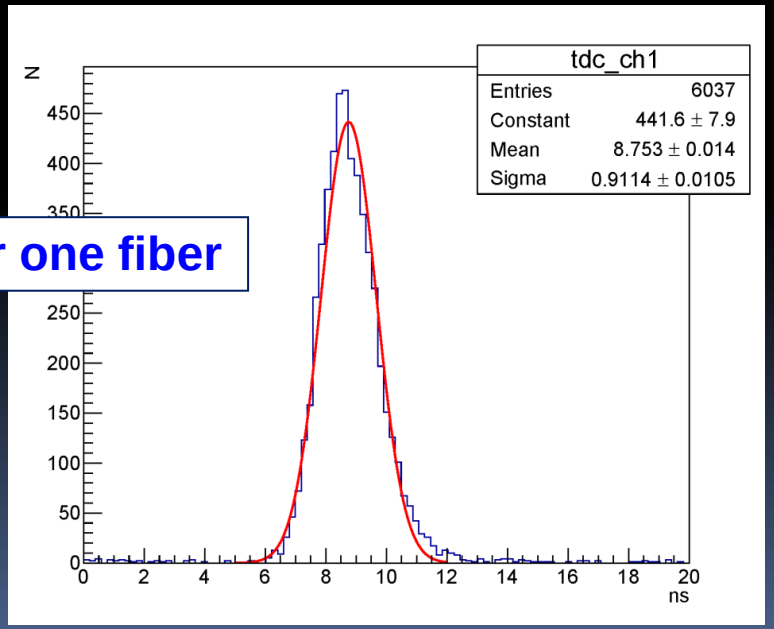


Preliminary

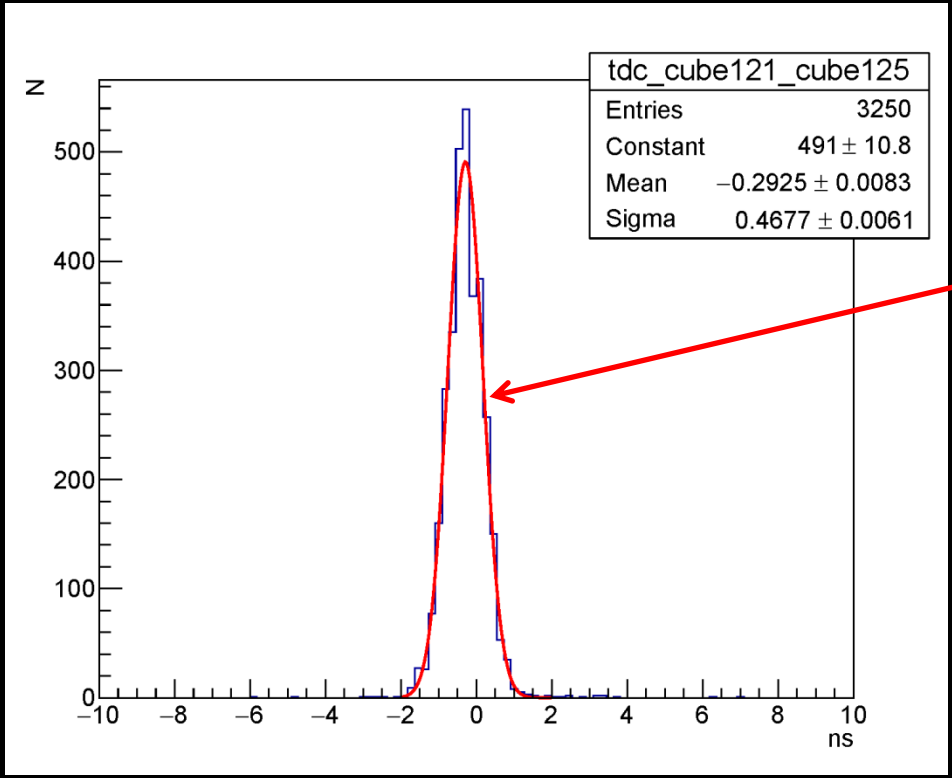




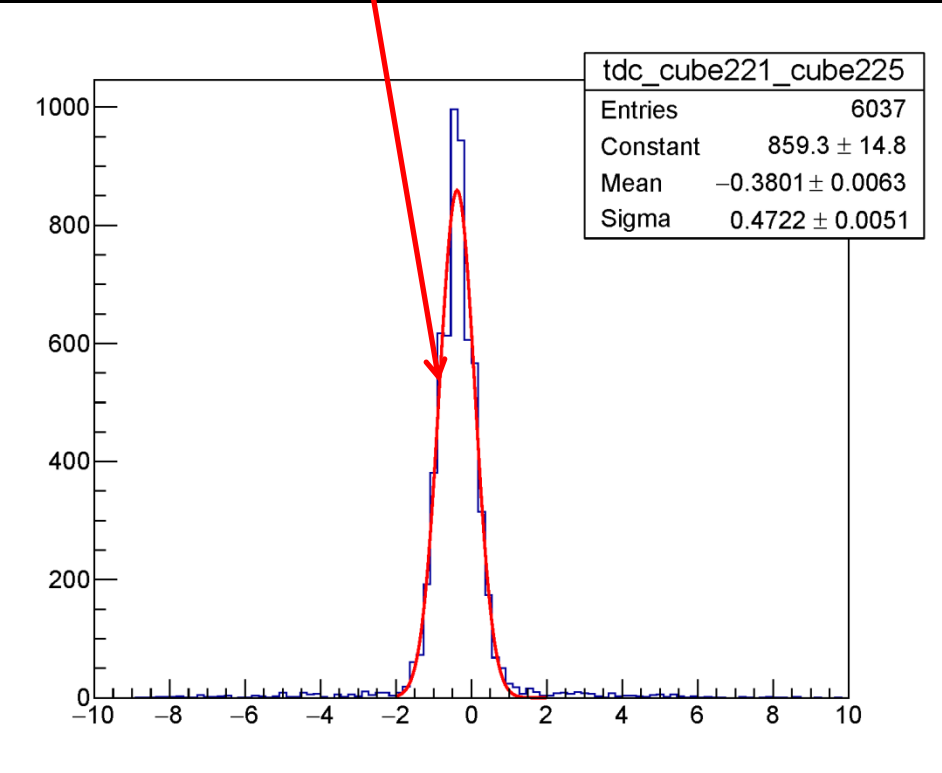
σ_t ~ 800-900 ps for one fiber



Timing (2)



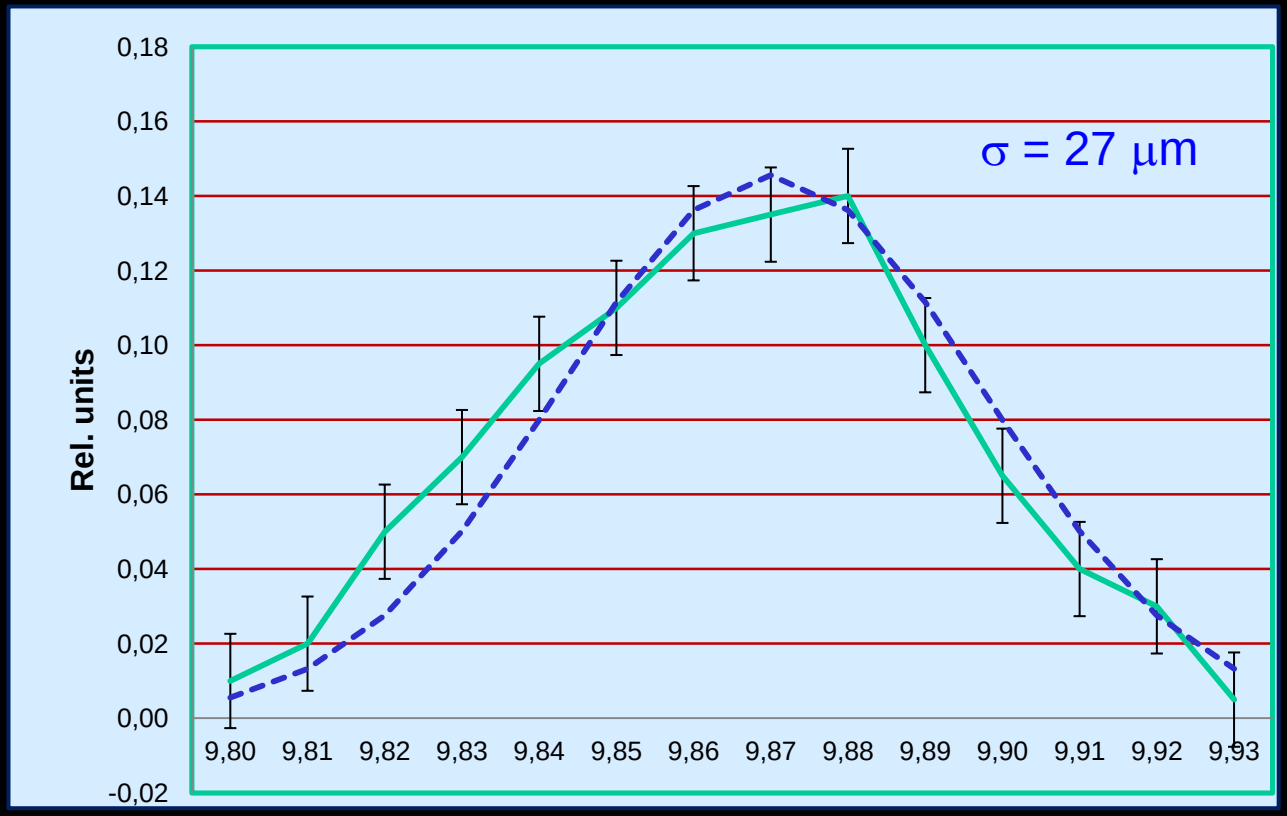
Signal sum of 2 cubes :
2 fibers from each cube → 4 fibers
σ_t = 470 ps



Very good performance:

- ~ 40-45 p.e./MIP for one fiber
  → 120-130 per/MIP/cube
  → detection threshold ~ 30-40 keV
- 800-900 ps/fiber → ≤ 500ps/4fibers
- Cross-talk ~3%

Accuracy of manufacturing



100 cubes

- measurement of 2 sides after cutting σ = 27 μm
- measurement of 1 side (extrusion thickness) σ ~ 100 μm

R&D to improve precision : 1- extrusion + machining
or 2- injection molding

Large prototype/pilot 3D SSD detector

Aim to develop and make a pilot detector in 2018-2019

Full scale prototype **0.5 x 0.5 x 1.0 m^3**
250000 detectors of 1 cm^3 each
12500 readout channels WLS fibers/SiPM
Electronics – 1-5 GHz digitizers
Mechanics – thin strong box
Optical connectors
Assembly
Quality tests, calibration

- **R&D: extrusion, injection molding, precision, quality control…. electronics, mechanics….**
- **Beam test in 2018**

International collaboration

Proto-collaboration to make 3D SSD is formed

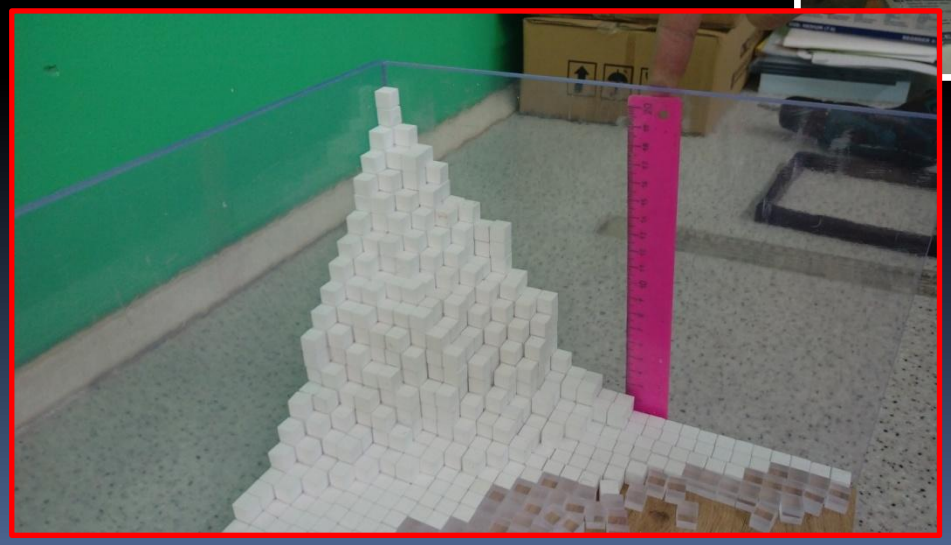
Russia	**INR**
France	**CEA/DAPNIA Saclay, Ecole Politechnique, LPNHE -Paris**
Switzerland	**University of Geneva, CERN (Neutrino platform)**
Italy	**INFN/ University Roma, Padova**
Poland	**NCBJ, Warsaw**
	+
Japan	**KEK, Tokyo University, Kyoto University**

Strong support from CERN Neutrino Platform

Great interest from LBL experiment DUNE
US : BNL, U. Rochester, U. Pittsburg, Stony Brook, LSU…
UK: Oxford, Imperial
Reactor experiments
Oxford (Solid experiment)

Mass production: stage 1

10000 cubes manufactured by Uniplast, Vladimir



Summary/Plan

- Novel 3D SSD neutrino detector is under development
- Small prototype demonstrates good performance
- International proto-collaboration formed
- Next step: 2018-2019 development, construction and test of large scale prototype/pilot detector
- Beam test in 2018
- Our plan: 5 x 5 x 5 cm^3 $\rightarrow$ 50 x 50 x 100 cm^3 (pilot) $\rightarrow$ full scale ($\geq$ 1 t) detector s