Light Collection in LAr for DUNE Near Detector

Joint Institute for Nuclear Research

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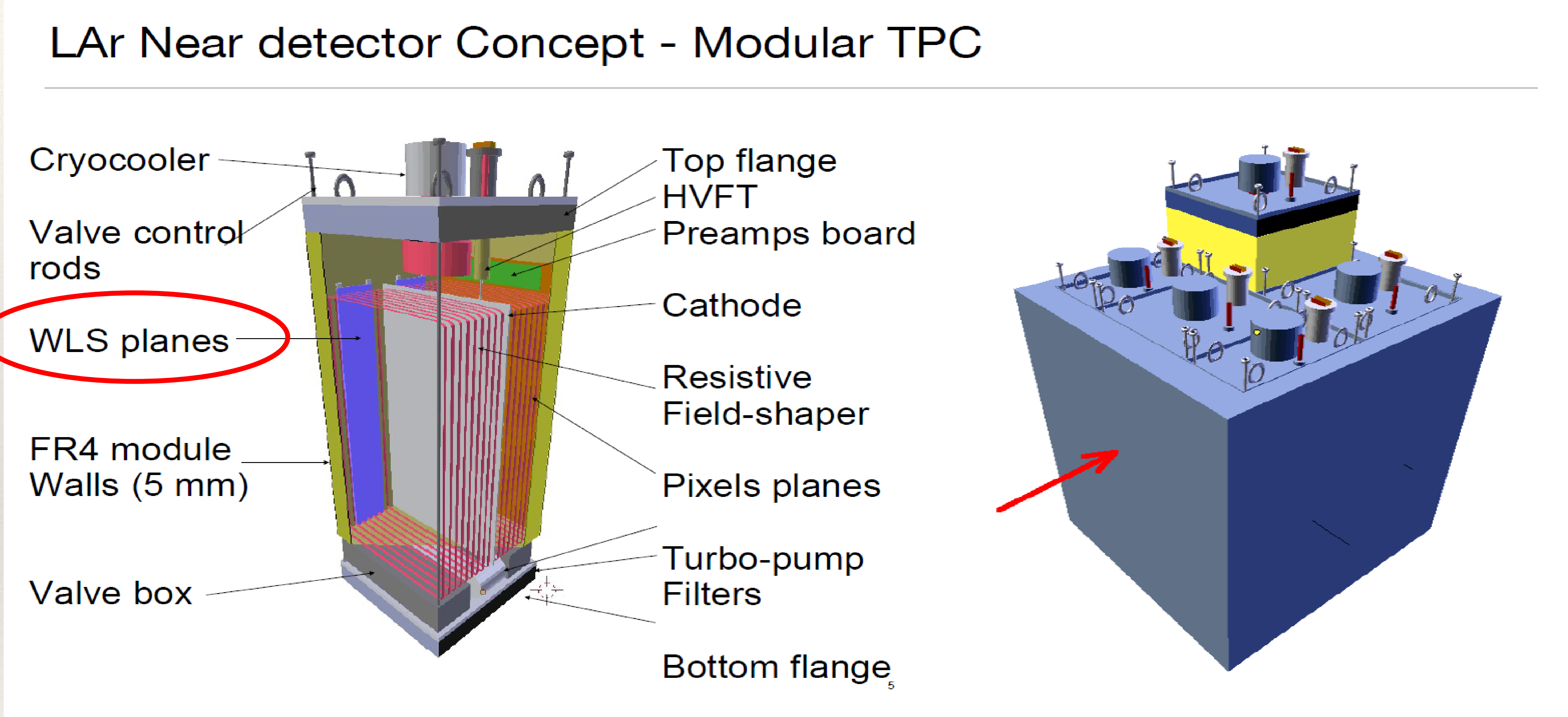
Presented by D. Denisov, Fermilab

DUNE Near Detector Workshop, Fermilab, March 28 2017

LAr TPC Option

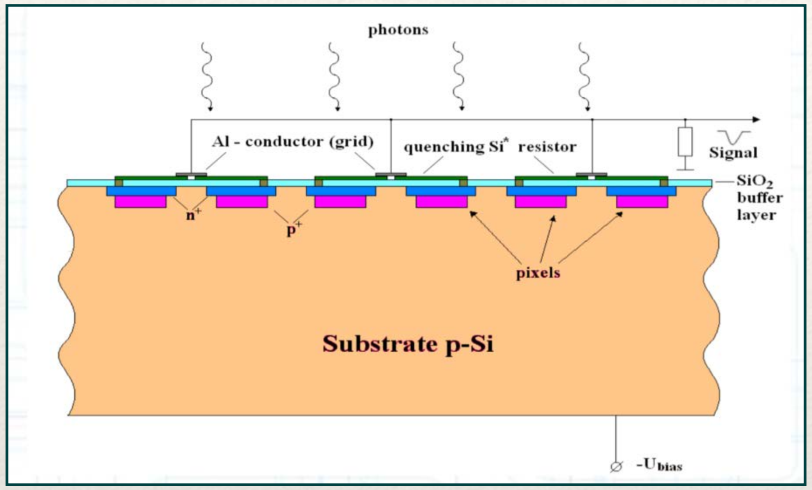


Yesterday's talk by: James Sinclair (University of Bern)

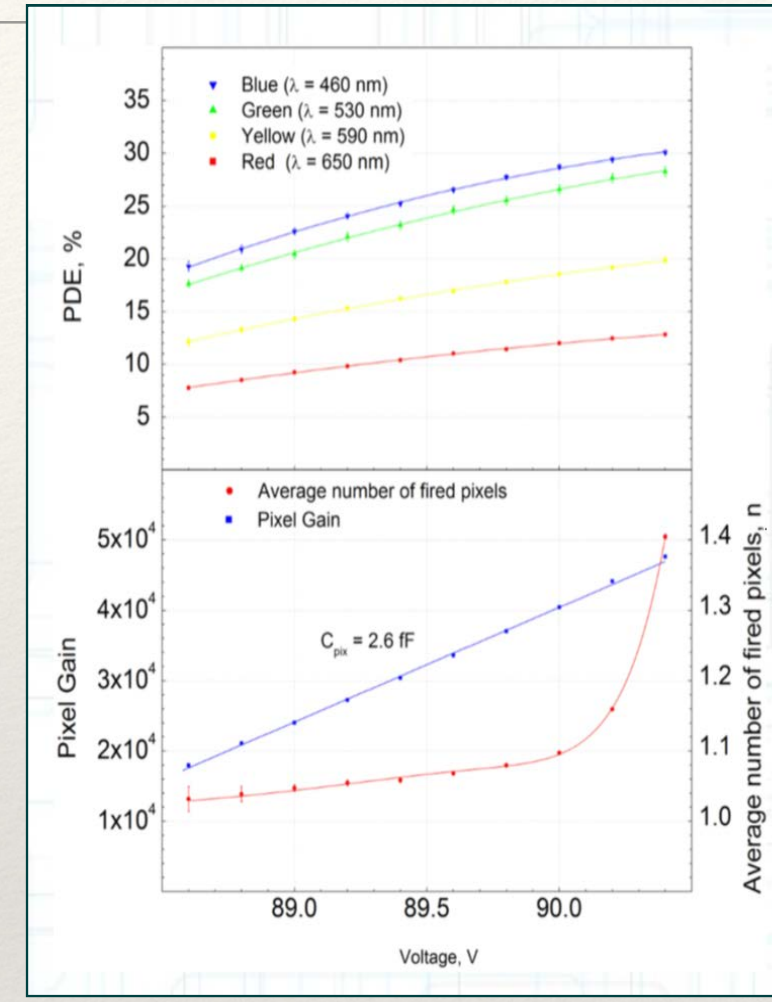
Challenge of LAr TPC is long drift time/pileup – precision time measurement is important

JINR Group Experience with SiPMs

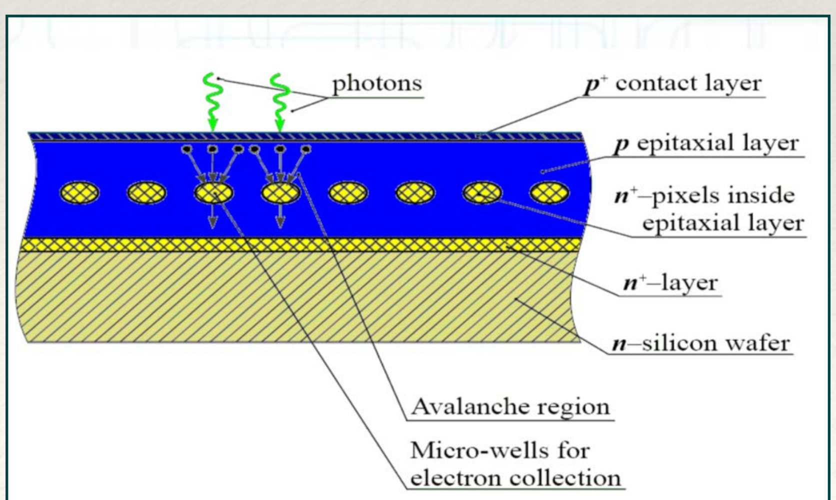
SiPM surface-pixillated structure



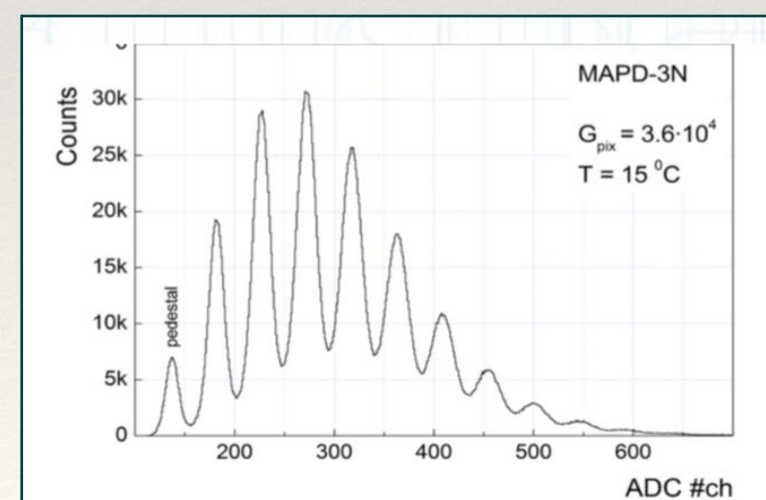
Surface-pixillated SiPMs are produced by many companies now



Another SiPM type: Deep MicroWell - DMW-structure



- JINR group has been conducting SiPM R&D over 20 years - Z. Sadygov and others
- Unique development at JINR is DMW-SiPM - promising for cryogenic temperatures applications



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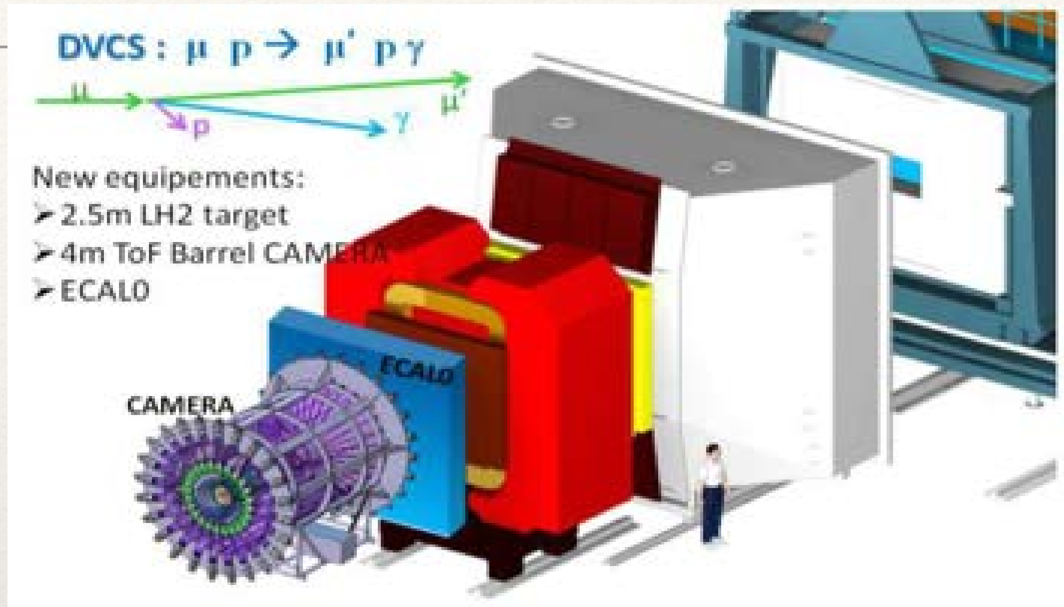
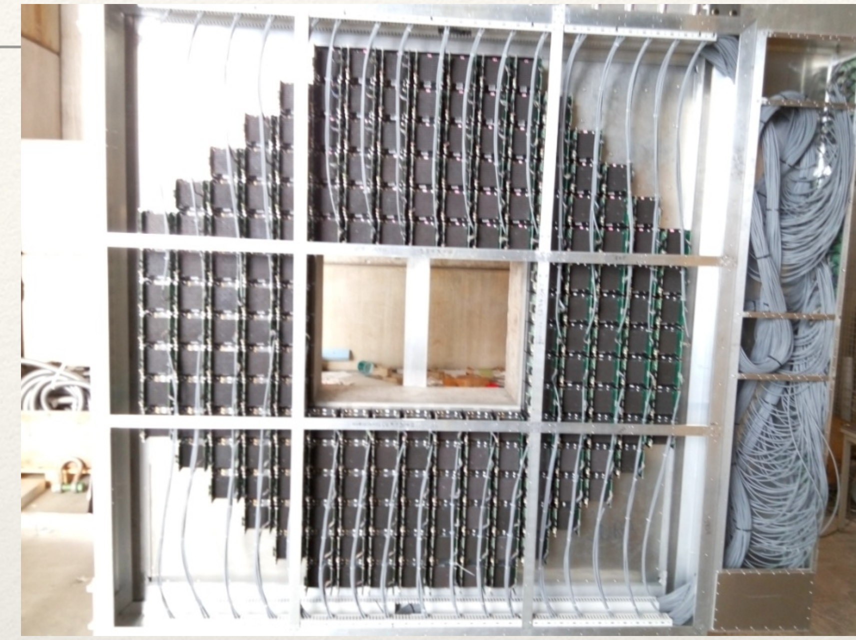
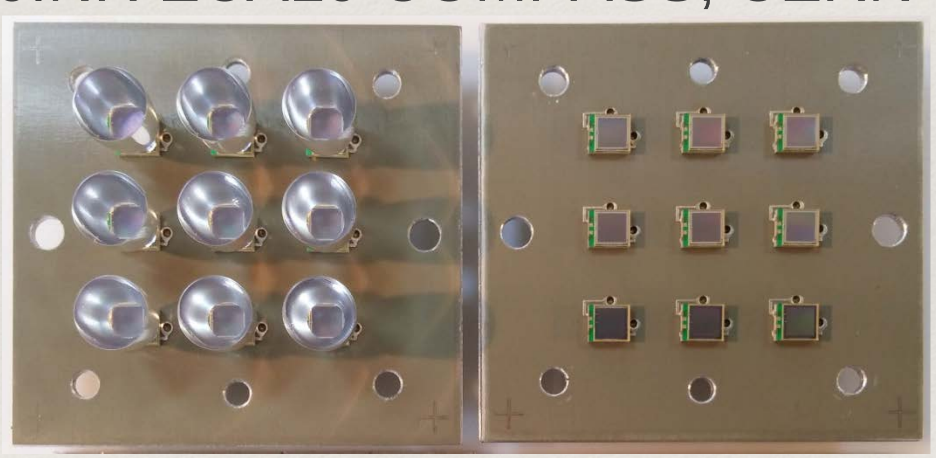
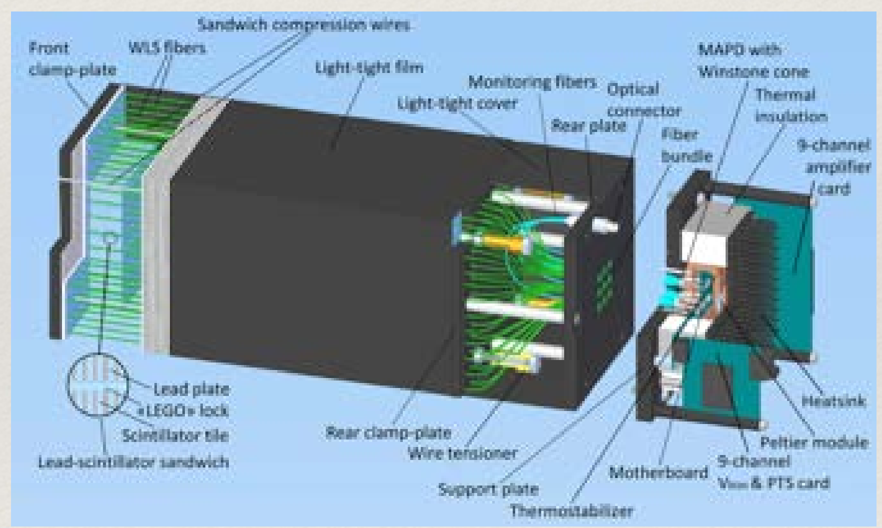
COMPASS Electromagnetic Calorimeter

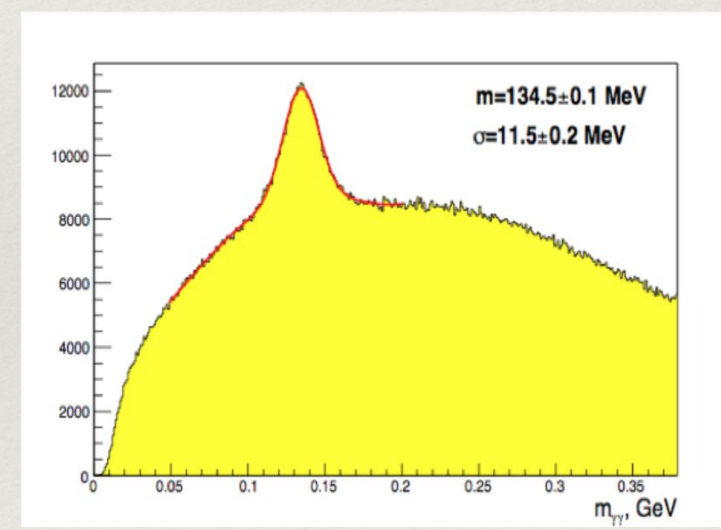




JINR ECAL0 COMPASS, CERN



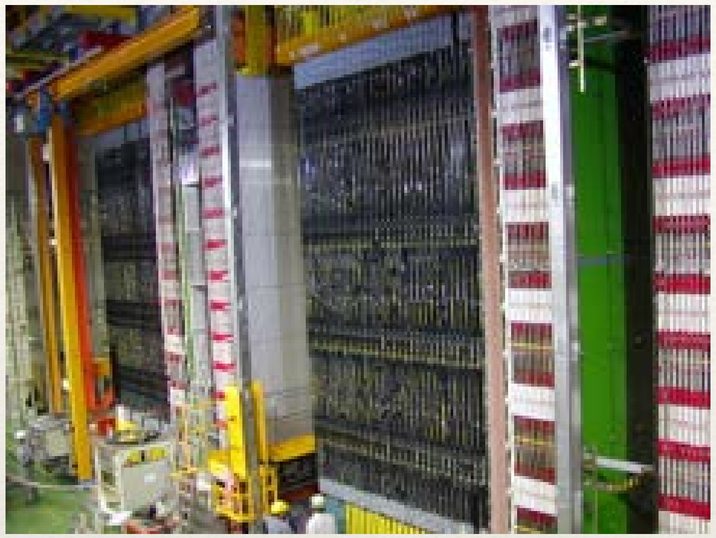


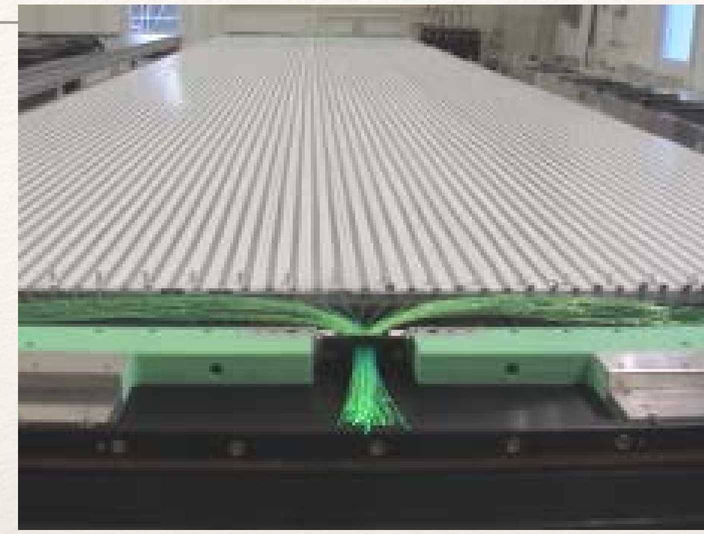


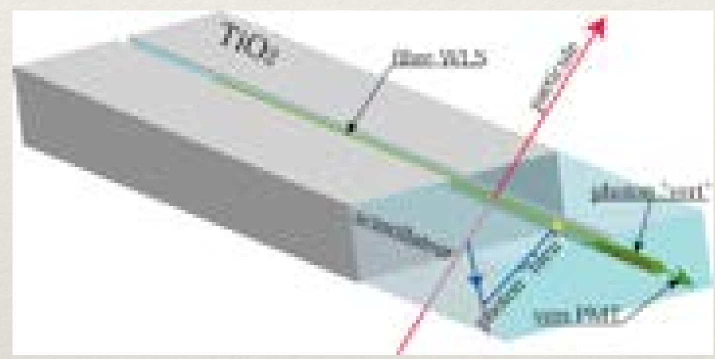
- 194 modules with individual temperature stabilisation
- 144 WLS-fibers per module in 9 bundles with Winston cones
- 1746 SiPM readout channels with stabilised LED monitoring

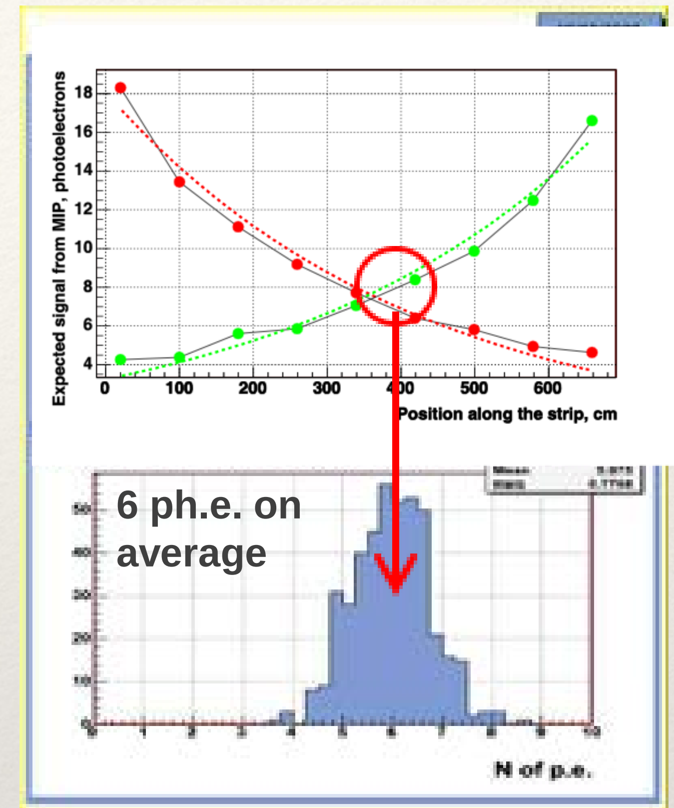
The same technique is used for NICA/MPD experiment at JINR

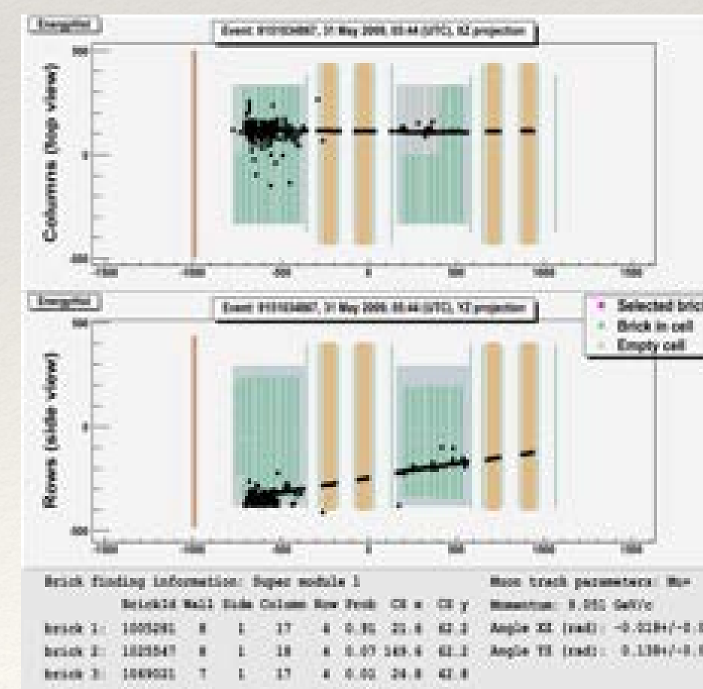
Opera Target Tracker Experience











Opera Target Tracker (TT): 6000 m^2

~32000 strips of 2.6 ✕ 1 ✕ 680 cm^3, light collected by Kuraray Y11 ⌀=1mm fibers and registered by multi-anode Hamamatsu PMTs

JINR developed strip production at ISMA (Kharkov). Participated in TT modules assembly and calibration. Responsible for the TT data analysis.

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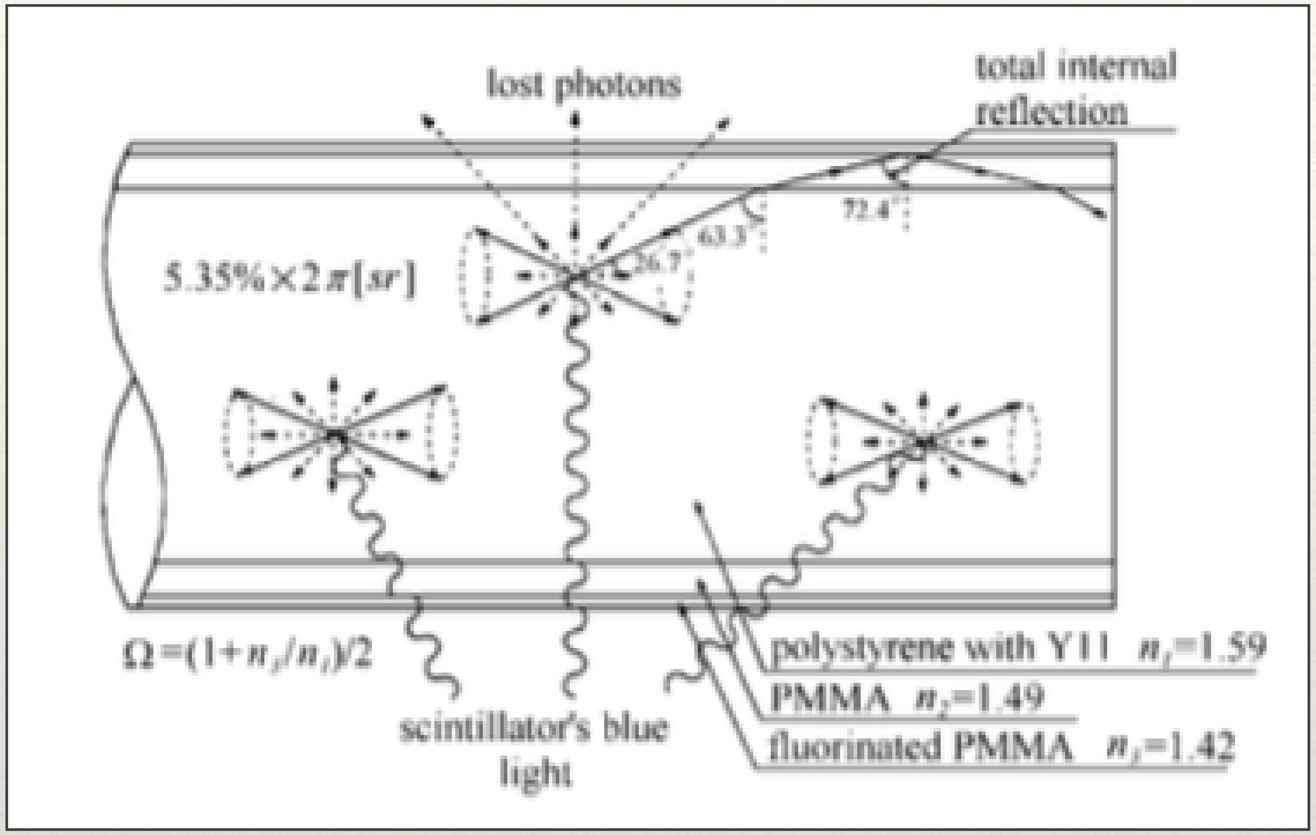
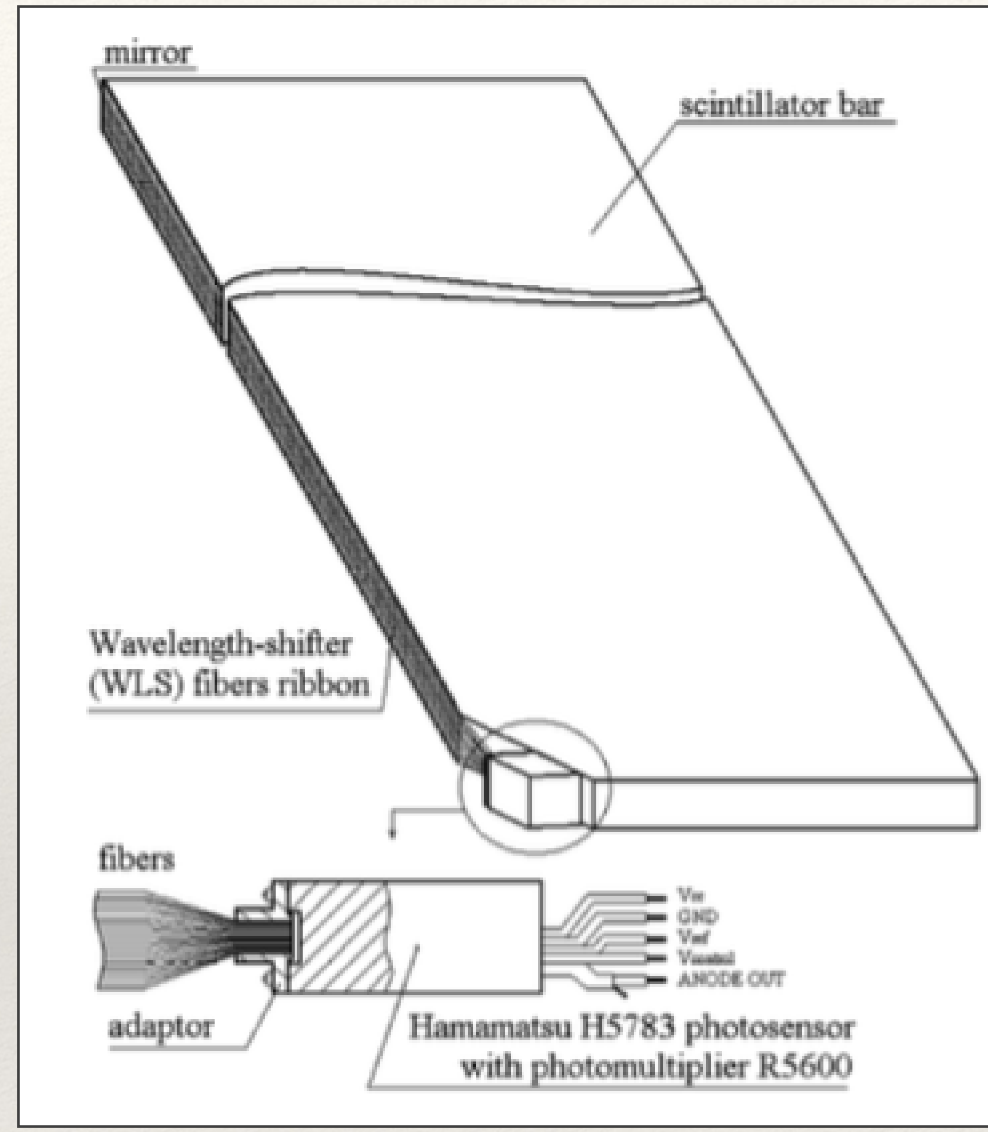
Light Collection CDF Muon Counters





WLS-Fiber may capture of up to 5% of incident light[1]

[1] A.Artikov et al., Design and construction of new central and forward muon counters for CDF II. NIM A538(2005)358-371

CDF forward muon counters geometry provides ~ 30 ph.e. with PDE_{PMT} = 15 % -> 200 photons

Thickness 1.5 cm -> 3.3 MeV per MIP -> ~ $3{\cdot}10^4$ photons

Total collection efficiency ~ 0.7%

LAr Light Detection Evaluation

- $5 \cdot 10^4\ \gamma$ @128 nm/MeV at 0 kV/cm, ~ 15% less at 1kV/cm [1]
- Tetraphenyl Butadiene (TPB) as a primary shifter - 128 nm -> 425 nm
- Detector area 4 x 5m^2 + 2 x 1m^2 = 22 m^2 ("Argontube design"),

  ~ $1.9 \cdot 10^3\ \gamma/\mathrm{m}^2/\mathrm{MeV}$

ρ = 1.4 g/cm^3 for LAr, MIP lose 3 MeV/cm, minimum distance = 1m,

E_{loss} = 300 MeV -> $5.7 \cdot 10^5\ \gamma/\mathrm{m}^2$

- If light registration module size is 30 $\times$ 30 cm ~ 0.1 m^2 ~ $5 \cdot 10^4\ \gamma$
- Target light collection efficiency ~1 %
- Expected number of ph.e. - $N_{ph.e.} = \varepsilon_{TPB} \times \varepsilon_{collectin} \times PDE_{SiPM}$,

ε_{TPB} ~ 0.5 due to 2π light loss (TPB efficiency ~1) [2], $\varepsilon_{collection}$ ~ 0.01, PDE_{SiPM} ~ 0.3

$N_{ph.e.}$ ~ 75 ph.e./module

[1] - T. Doke, H. J. Crawford, C. R. Gruhn et al., “Scintillation yields by relativistic heavy ions and the relation between ionization and scintillation in liquid argon”, Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment 235 (1985) 136 – 141. doi:10.1016/0168-9002(85)90254-2.

[2] - V. M. Gehman et al., “Fluorescence Efficiency and Visible Re-emission Spectrum of Tetraphenyl Butadiene Films at Extreme Ultraviolet Wavelengths”, Nucl.Instrum.Meth. A654 (2011) 116-121 arXiv:1104.3259 [astro-ph.IM] LA-UR-11-10447

Plans

Optimization of LAr scintillation light collection using SiPM

- We will consider different designs with TPB applied on: WLS-fiber ribbon, bulk+WLS-fibers, Dichroic filter (ARAPUCA-like), etc.
- Simulations of light collection for different designs and dimensions
- Will make prototypes of the light detection modules of different designs
- Test and optimize: efficiency, reliability, simplicity, cost
- Test in cryogenic conditions at Liquid Nitrogen at JINR
- Test in LAr at Bern University
- Develop the proposal for the optimized design

Dubna, JINR group

First Measurements

- Starting with WLS-plastic bulk of $10x10cm^2$
- Illuminating by stabilized light intensity LED @ 425 nm
- Applying different reflective materials at the bulk
- Dichroic mirror testing and application
- Cross check with simulation