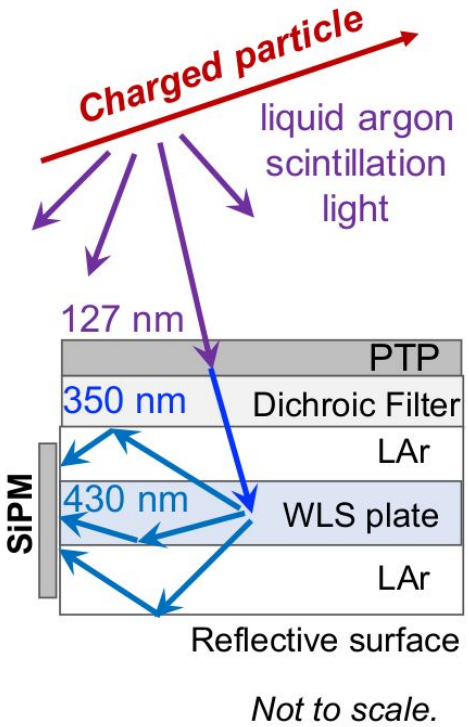
Attivita' @MiB su DUNE HD/VD PD collector e partner industriali

C.M. Cattadori,
Bologna 12/11/2021
DUNE-IT Meeting

Come ottimizzare & misurare la PDE della X-Arapuca

- Il dispositivo X-Arapuca (XA), e' unita' fondamentale del PDS in HD e in VD, ma con dimensioni moolto diverse.
- Rivelazione SN neutrino in VD (e HD) richiede una PD di 20 ph/MeV (0.5 min)→ XA PDE di ~2.5%(0.6% min): misure indipendenti di XA a 2 finestre hanno dato XA PDE:~2%



- ➢ Ottimizzazione WLS
- ➢ Ottimizzazione della finestra ingresso della trappola per fotoni X-Arapuca (che dal lato bottom ha coating dicrioco per trappola)
- ➢ Misura relativa della PDE della XA per HD al variare di
  - WLS manufacturer
  - SiPM: tipo e accoppiamento a WLS
  - Dichroic filter
- ➢ Misura assoluta PDE del dispositivo XA
- ➢ Ottimizzazione accoppiamento SiPMs-WLS (solo per VD)

Come migliorare la PDE di X-Arapuca

Ottimizzare WLS rispetto a prodotto commerciale (Eljin-286, the DUNE BL)

- 2019 inizia Attivita' R&D con gruppo Universitario (ScMat) UniMIB per sviluppo WLS in PMMA
  - crioresilienti
  - alta efficienza di conversione (350 nm->450 nm)
  - alta efficienza di "guida" di luce (qualita' delle superfici)
- Individuato Partner industriale (GlasstoPower) con know-how e capacita' di mass production, per produzione WLS per HD (48 x 9.3 cm^2) e per VD in singola tile dimensione 60 x 60 cm. ELJIN non ha interesse/possibilita' di produrre lastre di questa dimensione.
- Test e Misura relativa PDE di HD-XA al variare di
  - WLS (produttore)
  - disposizione del riflettore nella cella ottica

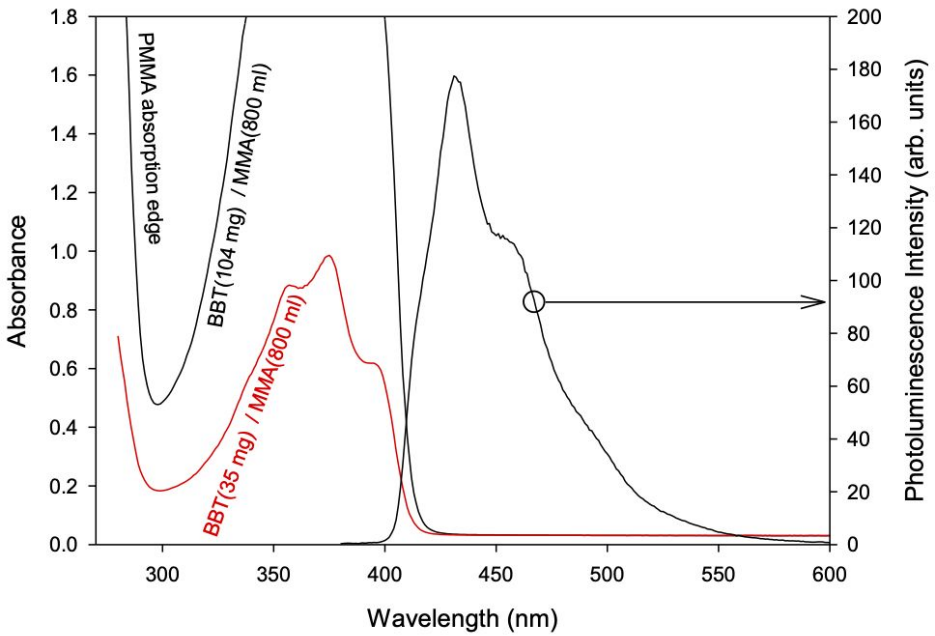
Glass to Power s.p.a

- Sede R&D: UniMiB
- Sede operativa e produttiva (nanofarm) a Rovereto (TN)
- Nata come spin-off di UniMiB, dal 2021 quotata sul mercato azionario EuroNext.
- Core business: concentratori solari trasparenti for produzione energia PV (finestre fotovoltaiche trasparenti)
- Tecnica proprietaria basata su Quantum Dots (assorbono visibile emettono IR) dissolti in lastre PMMA
- 2019: Iniziato R&D di produzione lastre WLS per DUNE
- Misure in criogenia con XA in Lab GERDA/DUNE in Bicocca

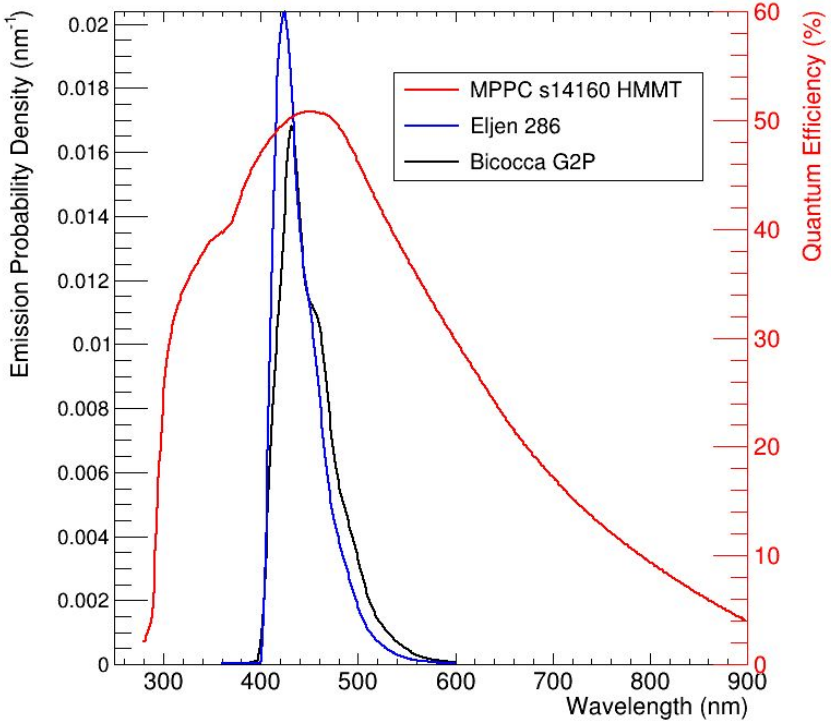
GLASS to POWER
e
TRENTINOSVILUPPO
IMPRESA INNOVAZIONE MARKETING TERRITORIALE
per
NANO farm
presso
Rovereto (TN)
POLO MECCATRONICA

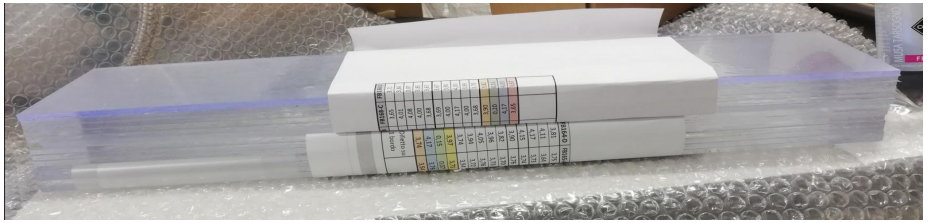
WLS sviluppati per DUNE: 2019-2020

Primo prototipo realizzato con molecola custom
(Università di Milano Bicocca)



The WLS production for HD



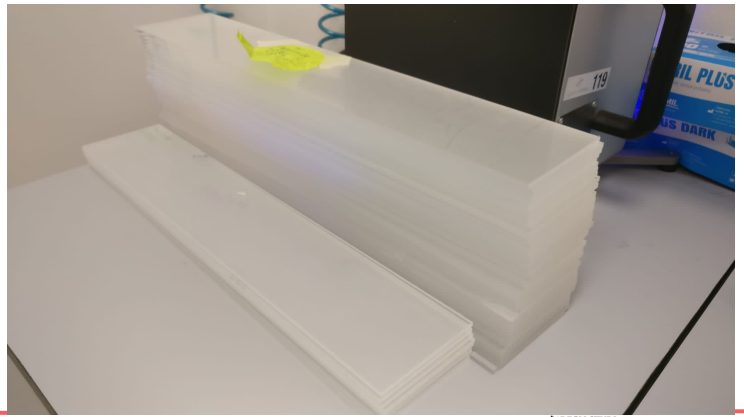


For HD, two manufacturers

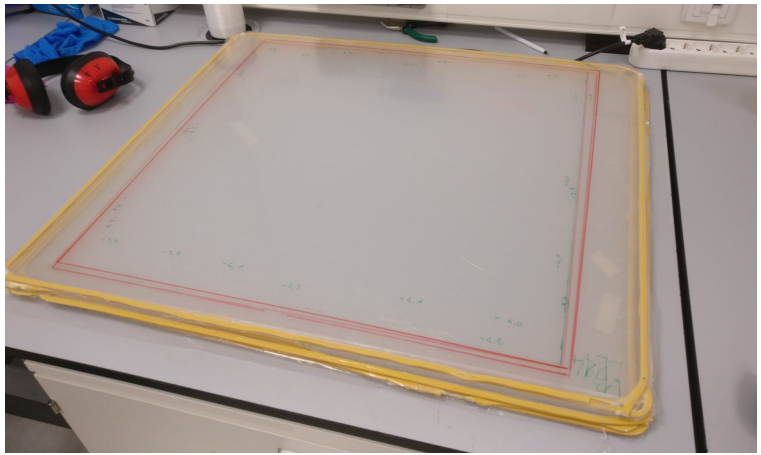
- Eljin (PVT /PS based WLS)
- Glass to Power (PMMA based WLS)

Glass to Power

- July 2021: completed the production and delivered to UniCamp 90 pcs for the HD pDune Run2 in 2022.



5 VD WLS slabs for the two VD Prototypes for 2021 CERN coldbox test



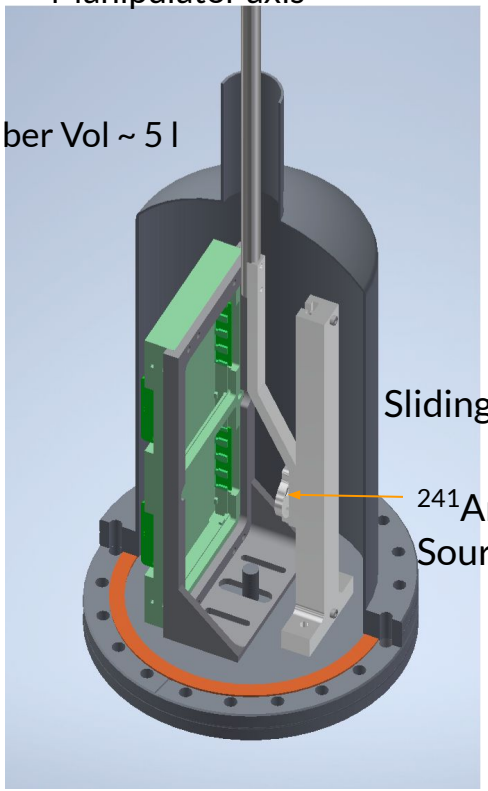
- July 2021: after a 5 month tuning of the casting reactor G2P completed the production of 5 pcs for the VD x (600 x 600 x 4) mm.
- Measurements of the attenuation length of the SC WLS ongoing: preliminar results ≥ 1 m).
- Possible R&D to further optimize the chromophore concentration for further tests
- Possible R&D to change both the substrate and the chromophore to optimize the detection of the light emitted by LAr-Xe mixtures

VD vs HD X-Arapuca: main facts

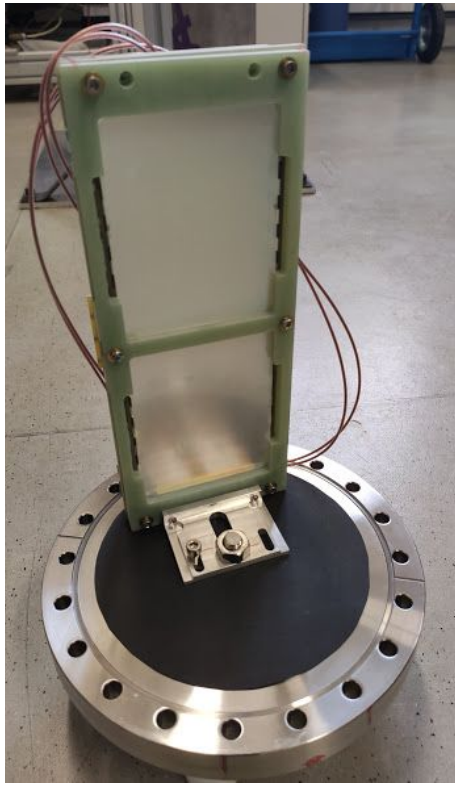
	Horizontal Drift	Vertical Drift	Ratio VD/HD
Size of the Ph. Collector	48 x 9.3 cm^2	60 x 60 cm^2	8.06
N. of SiPMs	48	160	3.3
N. of SiPM boards	8	8	-
SiPM/WLS area	3.9%	1.6%	0.4
d (WLS center- closest SiPM)	4.6 cm	30 cm	~5

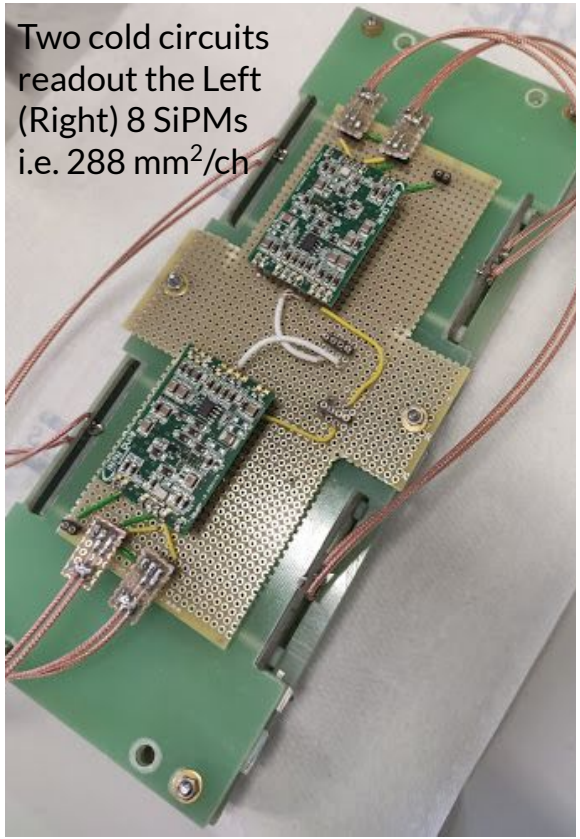
→ to match the VD XA PDE~3.5% while reducing a factor of 2.5 the n. of photosensors/unit area w.r.t. the HD XA → increase the conversion/detection efficiency in each step of the light conversion/detection process

The Milano Bicocca 5 l setup for the two window XA



SiPMs: 4x 4 HPK S14160-6050HS





Results: the PDE of the two windows XA Device

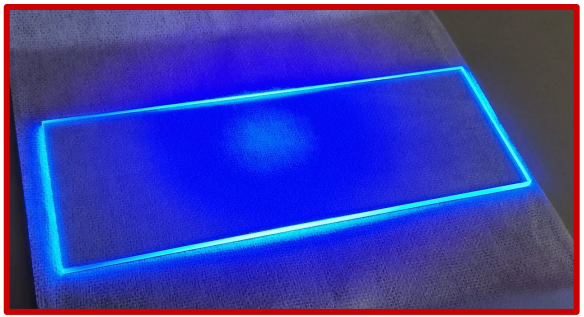
	EJ-286 w/o Vikuiti	EJ-286 w/ Vikuiti	FB118
SPE Gain (ADC·ns)	1680 ± 80	1690 ± 80	1735 ± 90
En. res. (σ/μ)	6.3 ± 0.2 %	6.0 ± 0.2 %	3.6 ± 0.1 %
S/N	6.8 ± 0.3	7.3 ± 0.3	7.3 ± 0.3
ϵ_{raw}	2.1 ± 0.1 %	2.3 ± 0.1 %	3.5 ± 0.1 %
τ_T	1294 ± 35 ns		
LAr purity correction	+ (1.4 to 2.6) %		
Cross-talk correction	- (18 ± 1) %		
ϵ	1.8 ± 0.1%	1.9 ± 0.1%	2.9 ± 0.1%

ϵ_{raw} , ϵ: Efficiency Prior (raw) and post corrections respectively

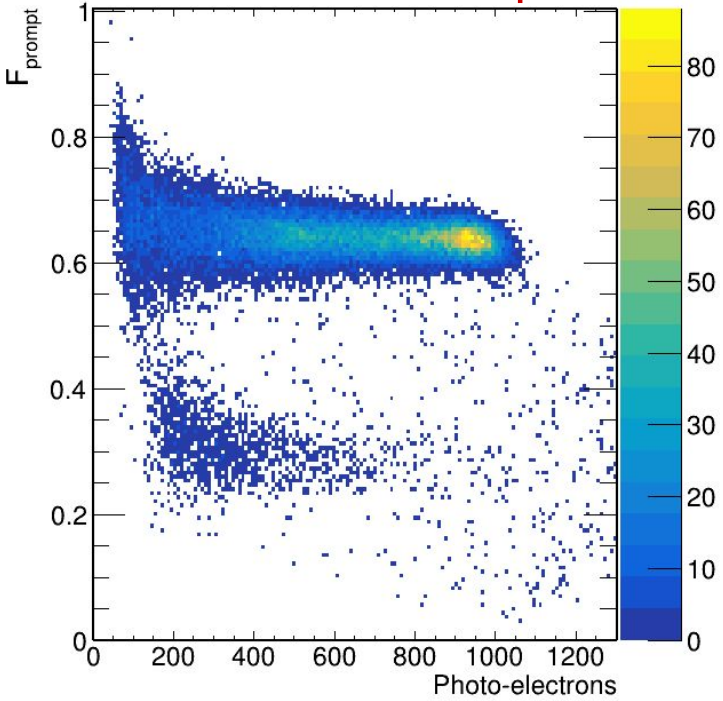
τ_T: measured Triplet half-life

Positions	G_ϵ
2,3,4	55 ± 5 %
5	50 ± 5 %
1	63 ± 6 %

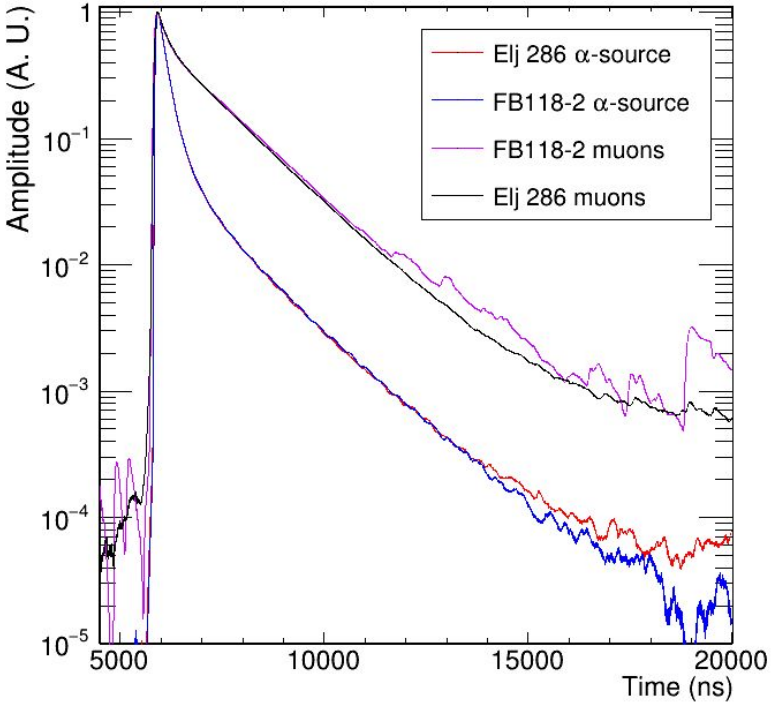
G_ϵ: PDE variation (FB-G2P bar w.r.t. The EJ bar)



PSD Features: Alpha/muon discrimination



F_{prompt} cut to select alphas (muons). The prompt contribution was integrated up to 600 ns



The normalized average waveforms of the events, selected on the F_{prompt} classifier

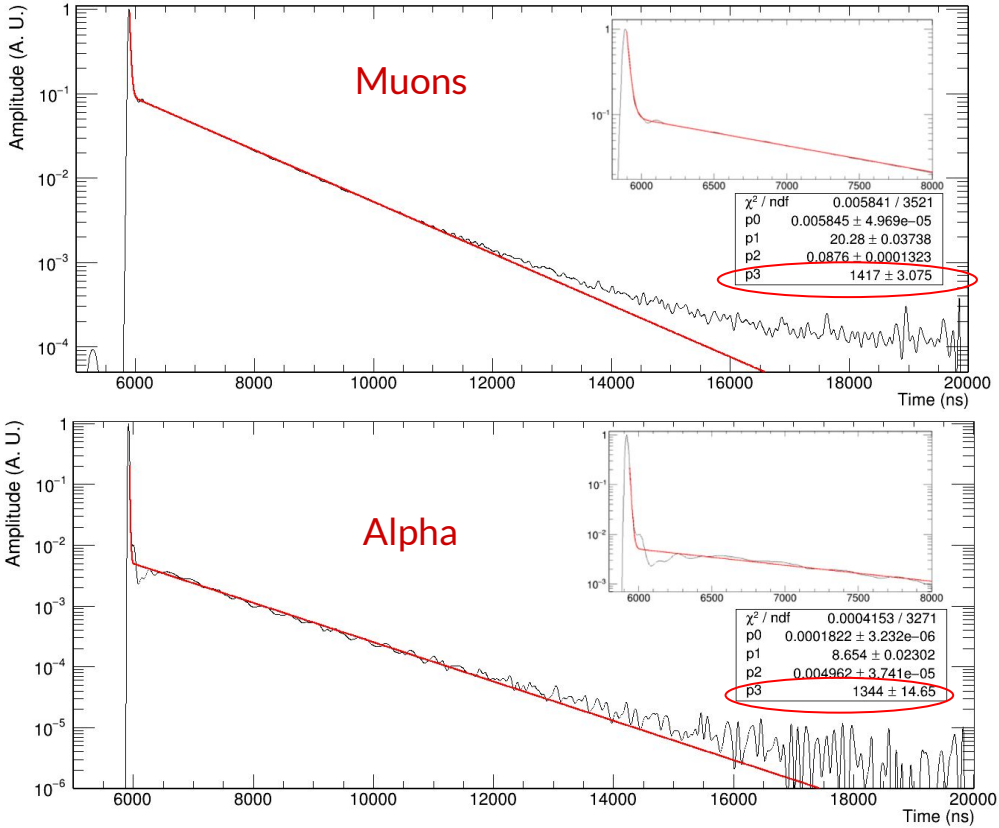
Waveforms Fit

The normalized average waveforms are deconvolved and fitted with

$$I(t) = A_S \exp\left(-\frac{t}{\tau_S}\right) + A_T \exp\left(-\frac{t}{\tau_T}\right)$$

A_S and A_T are the relative amplitudes and τ_S and τ_T the time constants of the singlet and of the triplet dimer states.

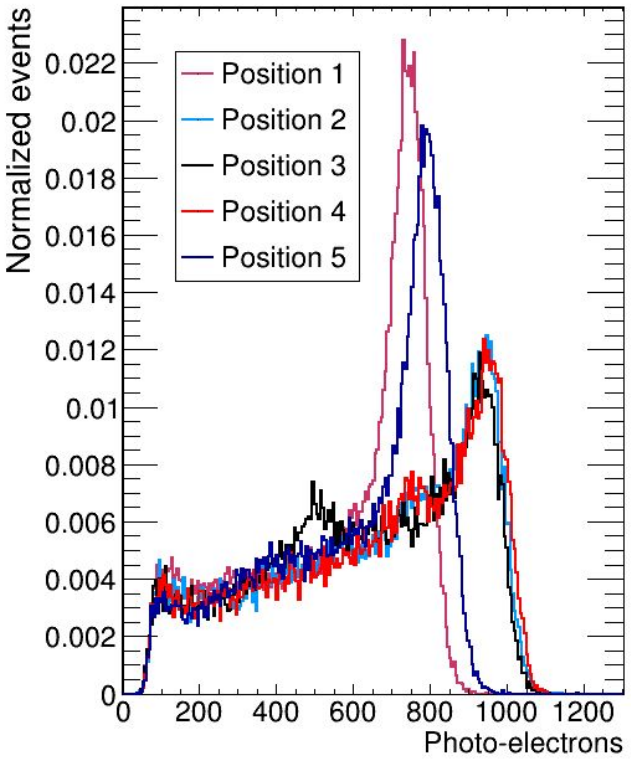
Both τ_S and τ_T were consistent for all the measurements → **LAr purity level controlled**



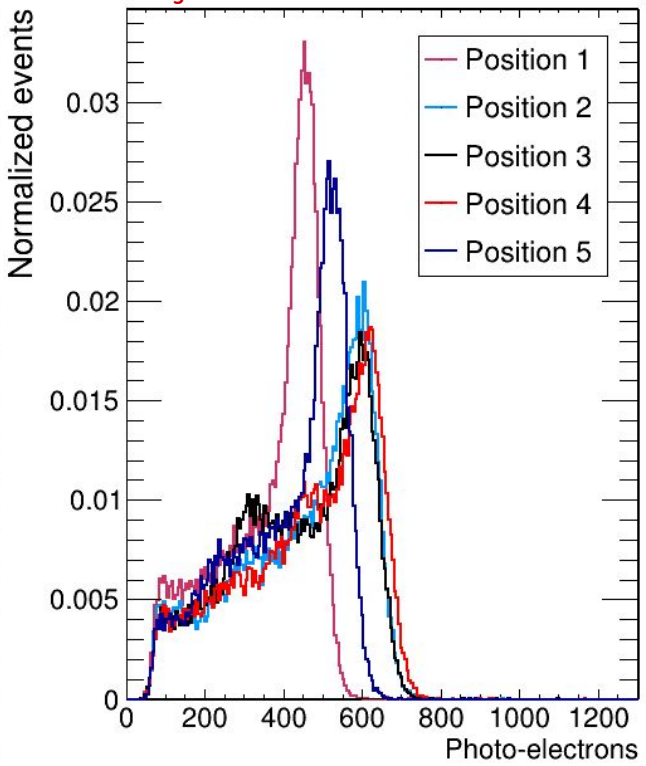
Results

Spectra cutting on F_{prompt}

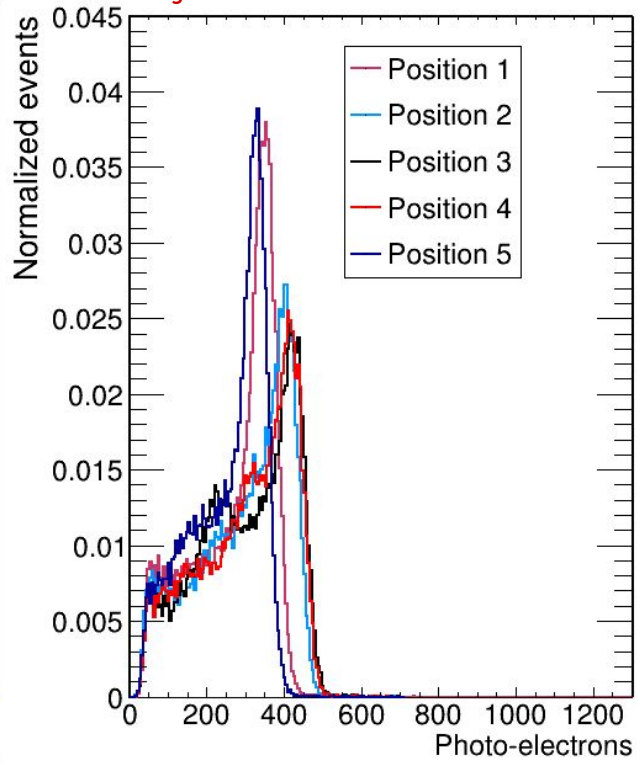
G2P with Vikuiti



Elj286 with Vikuiti



Elj286 without Vikuiti



Two Paper published:

JINST 8 (2013) C10007
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Jinst

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LIGHT DETECTION IN NOBLE ELEMENTS (LIDINE 2013)
29th – 31st MAY 2013, FERMI NATIONAL ACCELERATOR LABORATORY
ILLINOIS, U.S.A.

Liquid argon scintillation read-out with silicon devices

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Enhancement of the X-Arapuca photon detection device for the DUNE experiment

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ABSTRACT: In the Deep Underground Neutrino Experiment (DUNE), the VUV LAr luminescence is collected by light trap devices named X-Arapuca, sizing ~ (480 × 93) mm^2. Six thousand of these units will be deployed in the first DUNE ten kiloton far detector module. In this work we present the first characterisation of the photon detection efficiency of an X-Arapuca device sizing ~ (200 × 75) mm^2 via a complete and accurate set of measurements along the cell longitudinal axis with a movable ^{241}Am source. The MPPCs photosensors are readout by a cryogenic trans-impedance amplifier to enhance the single photoelectron sensitivity and improve the signal-to-noise while ganging 8 MPPC for a total surface of 288 mm^2. Moreover, we developed a new photon downshifting polymeric material, by which the X-Arapuca photon detection efficiency was enhanced of about +50% with respect to the baseline off-shell product deployed in the standard device configuration. The achieved results are compared to previous measurements on a half size X-Arapuca device, with a fixed source facing the center, with no cold amplification stage, and discussed in view of the DUNE full size optical cell construction for both the horizontal and the vertical drift configurations of the DUNE TPC design and in view of liquid Argon doping by ppms of Xe. Other particle physics projects adopting Liquid Argon as target or active veto, such as Dark Side and LEGEND or the DUNE Near Detector, may take advantage of this novel wavelength shifting material.

KEYWORDS: Noble liquid detectors (scintillation, ionization, double-phase); Photon detectors for UV, visible and IR photons (solid-state) (PIN diodes, APDs, Si-PMTs, G-APDs, CCDs, EBCCDs, EMCCDs, CMOS imagers, etc); Scintillators, scintillation and light emission processes (solid, gas and liquid scintillators); Neutrino detectors

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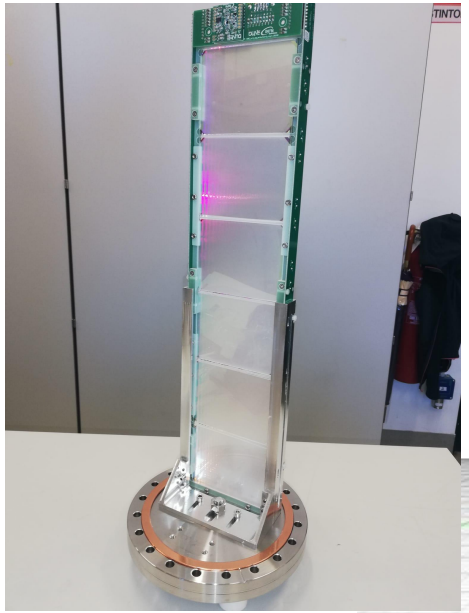
*Corresponding author.

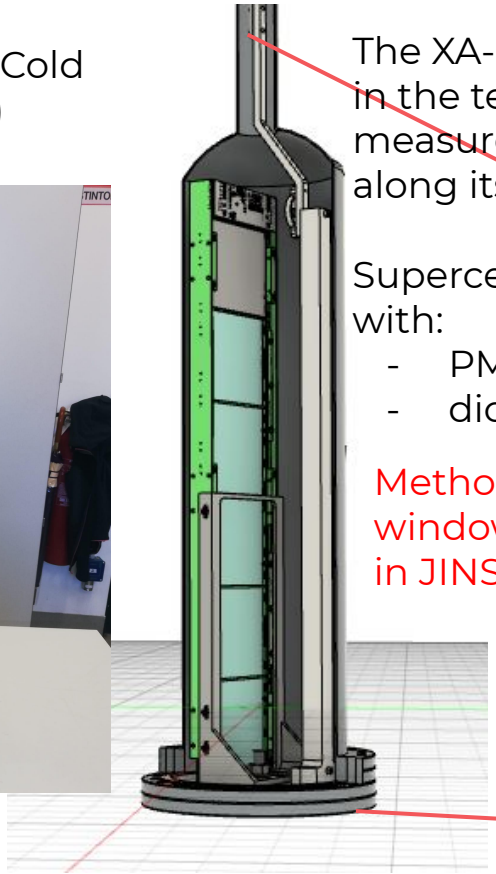
https://doi.org/10.1088/1748-0221/16/09/P09027

2021 JINST 16 P09027

Setup to measure the XA-HD-SC PDE in LAr

The XA-HD-SC w. Cold FE circuit (on top)



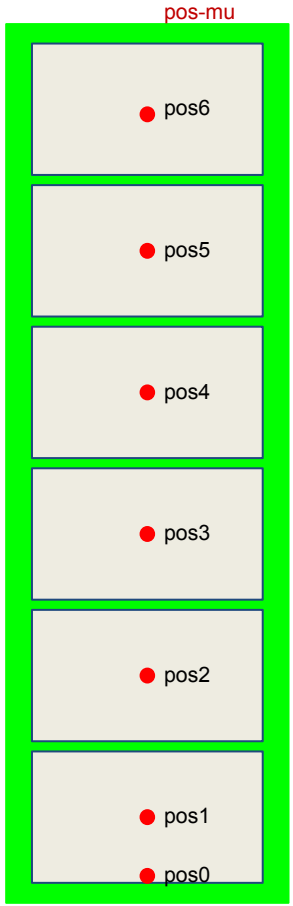


The XA-HD-SC installed in the test chamber to measure the PDE along its z-axis.

Supercell equipped with:

- PMMA WLS (G2P)
- dichroic filters

Method as for the two windows XA published in JINST 16 (2021) 09027



HD-SC Measurement: work in progress.

- Source-to-filters distance: ~5.7 cm (need to be remeasured).

SiPM bias: 45 V (+3 V OV for a 45% PDE).

- Reference SiPMs looking directly at the LAr (S13370 UV4 series) will be added to disantangle the measurements from the LAr quality

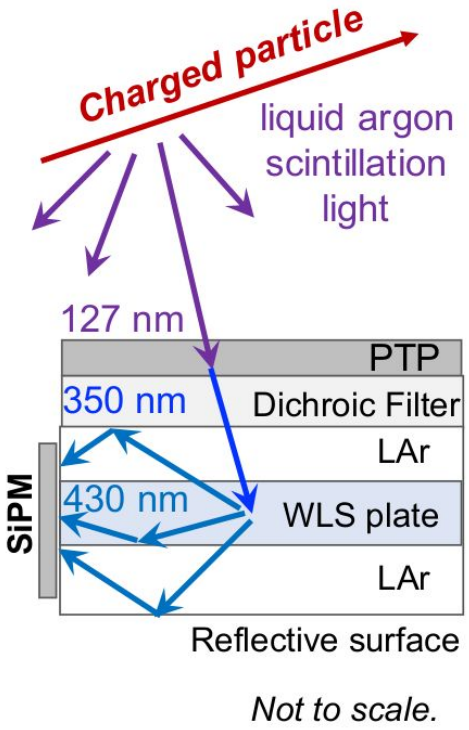
- Comparison of G2P vs “optimized” Eljin production (for HD)

- Tests with HPK and FBK SiPMs and HD Cold electronics
- Three fillings cycles and measurements already perfomed
- Work in progress

Sviluppo di filtri dicroici per VD and HD

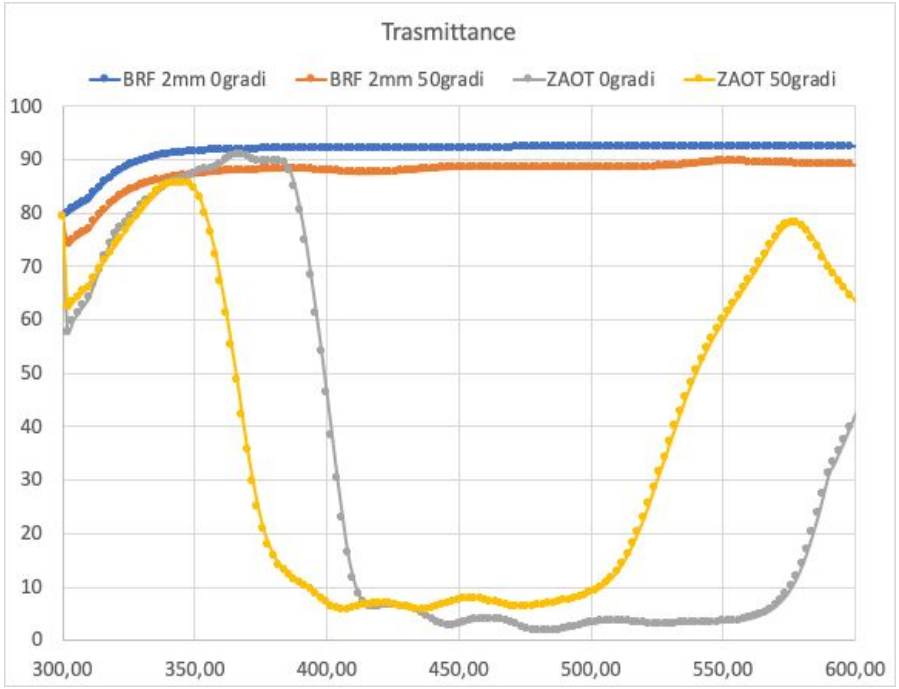
The XA-PDE depends largely on the reflectivity of the dichroic that acts as a trap for the photons that leave the WLS and must be bounced back to the WLS/SiPMs

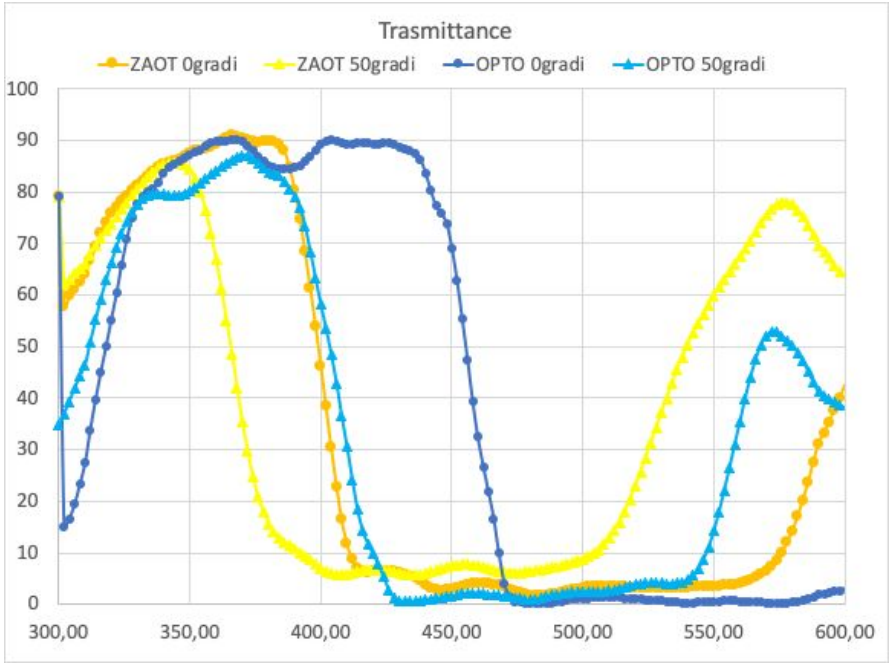
- the reflectivity of the dichroic depends on the incident angle and on the quality and number of coating layers
- so far only one manufacturer (OPTO Brasil)
- look for another with the aim to improve the reflectivity at small angles
- found an industrial partner (ZAOT) already involved in scientific projects (CTA et others)



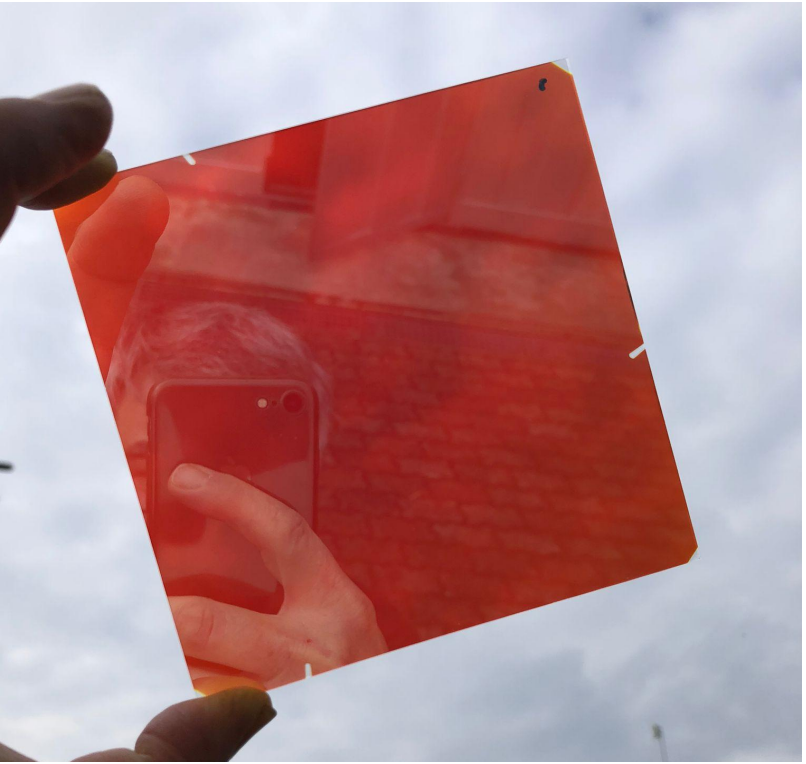
Trasmittance of the ZAOT dichroics prototypes

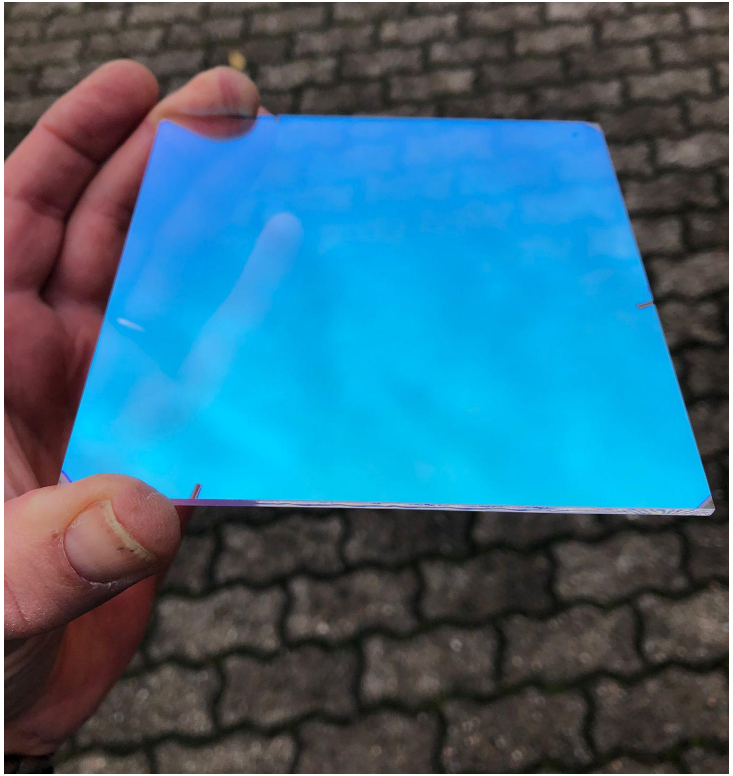
Chosen a different borosilicate substrate in thickness 2 mm: this will allow to have 9 x (20 x 20 cm) filters in the VD tile insteda of 36 x (10 x10 cm)





ZAOT Dichroics prototypes





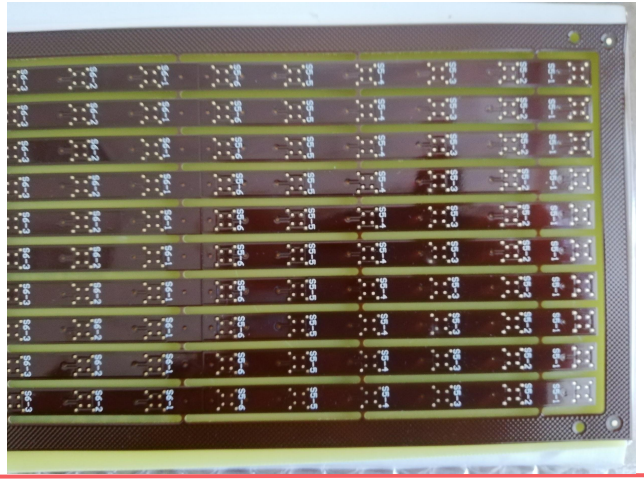
ZAOT s.r.l.

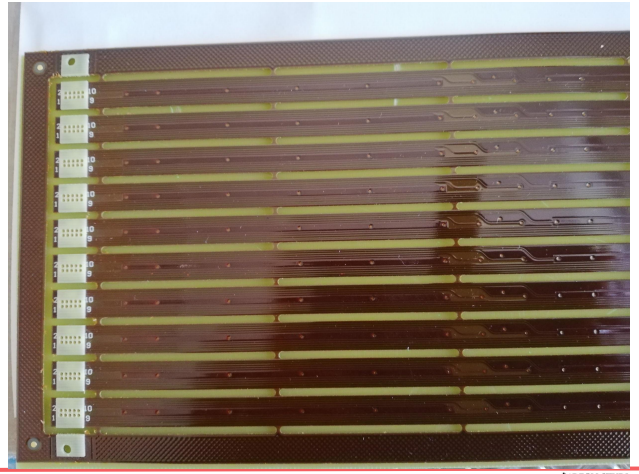
ZAOT: specializzata in coating ottici a film sottile (PVD) per ottica di precisione, aerospaziale e astronomia.
Gia' partner Industriale di

1. Università di Trento – Dipartimento di Fisica
2. La Sapienza – Università di Roma – Dip. Ingegneria dell'Informazione, Elettronica e Telecomunicazione
3. Università di Padova - Department of Physics and Astronomy
4. INAF – Brera Astronomical Observatory
5. CNRS LUPM - U. Montpellier
6. Observatoire de la Côte d'Azur
7. INFN (subcontractor per CTA)

Optimization of SiPMs to WLS optical coupling

- SiPMS will be glued (with cryoresilient&transparent glue) to WLS
- For this, to accomodate tolerances and not put stress on glued SIpms , they will be supported by flex circuits (designed by INFN-Statale).
- Test at MiB in the framework of the HD XA tests
- No passive ganging
- Each flex hosts 24 SiPM to comply to the HD cell SiPM coverage





Conclusioni

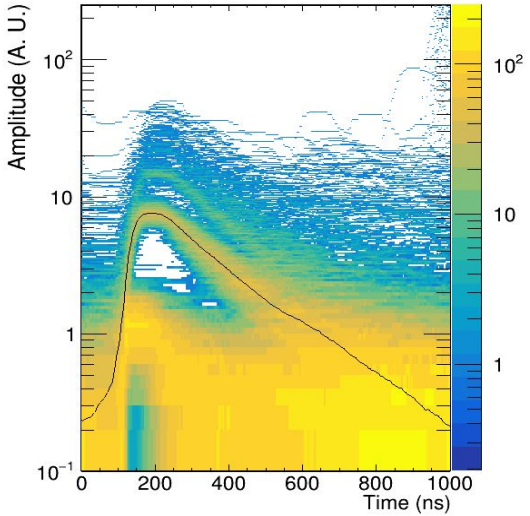
- Per massimizzare la raccolta di luce della XArapuca, unita' ottica del HD e VD, ottimizzazione di
  - WLS (anche sigillatura con Al coating dei gap fra SiPMs)
  - Filtri dicrioci
  - Accoppiamento SiPMs to WLS
- Individuati partner industriali con capacita' di mass production
- G2P: ha gia' prodotto
  - 90 WLS per HD per XA-SC per PDune II
  - 5 WLS per VD (due sono stati utilizzati in Coldbox#1)
- INFN MIB ha misurato enhancement della PDE di ~50% XA con WLS G2P invece che con EJ-286
- ZAOT: ha prodotto in questi giorni
  - prototipi filtri dicroici per VD ma utilizzabili anche in HD
  - curve T/R indicano importante miglioramento a bassi angoli incidenza
  - test in criogenia e su XA-HD saranno fatti a lab INFN-MiB sui prototipi
- Attivita' accoppiamento SiPMs-WLS programmata e progettata (scelte le colle) ma non ancora realmente entrata nel vivo
- Metodo di misura della PDE della XA in LAr definito e pubblicato

Extra

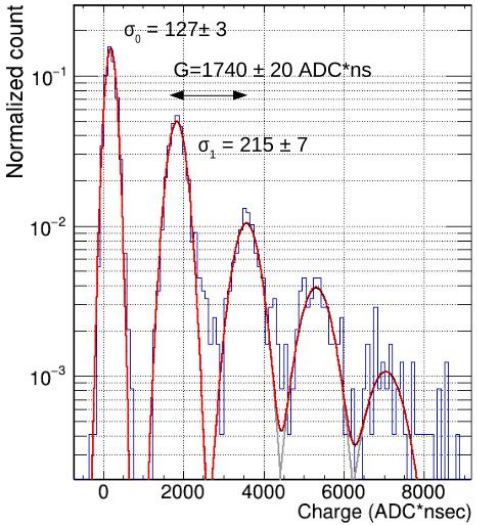
Comparison (2 dichroics XA vs. XA-HD tests)

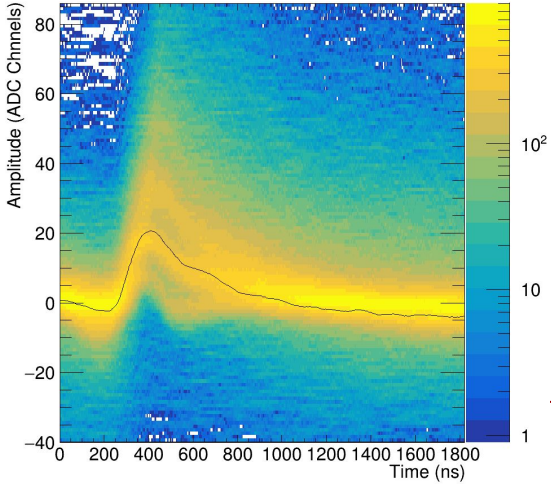
	2x window XA tests	6x window XA HD	36x window XA-VD
Size of the WLS slab (sipm/WLS) area	204 x 75 mm^2 = 150 cm^2 3.8%	480 x 93 mm^2 = 450 cm^2 3.9%	600 x 600 mm^2 = 3600 cm^2 =1.6%
SIPMs	HPK S14160-6050HS +2.7 OV (50% PDE)	HPK DUNE-75um-HQR +3V OV (45% PDE)	
Ganging	x 8 (2 boards x 4 SIPMS)	x 48 SiPMs	4x 40 (2 flex bds x 20 SIPMS)
# channels	2	1	4/2
SiPMs -Cold Amp. Cold Amp dyn. range	DC	AC 2000 ph.e.	
s.ph.e. (50 Ω, 45 V)	0.98 mV	2.2 mV	
Chamber volume	~ 5 l	~ 10 l	

Comparison SPE and S/N

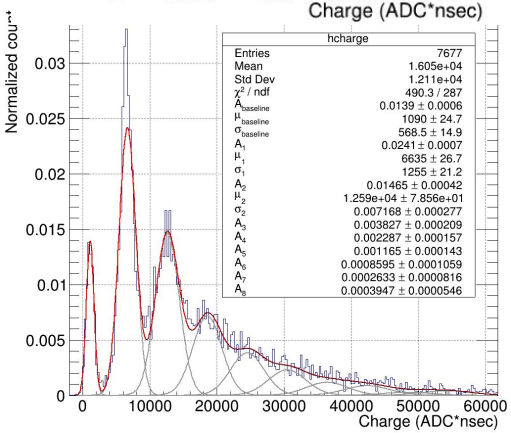


2 window XA
JINST work
S/N ~ 7





6 window XA
HD-SC
S/N ~ 4.9



C