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Online control of the gain drift with temperature of SiPM arrays used for the readout of $LaBr_3$:Ce crystals

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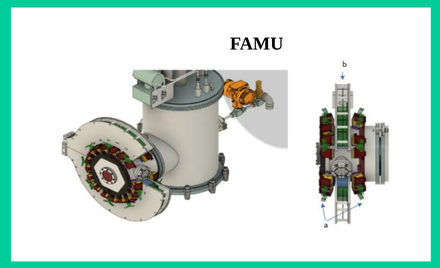
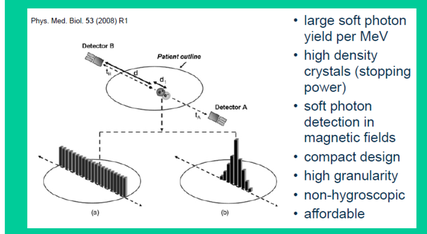
Introduction

- Compact X-rays detectors, based on crystals with SiPM array readout may find application in many fields:
  - TOF PET imaging
  - Fundamental physics: measure of the Zemach proton radius (FAMU at RIKEN-RAL)
  - Homeland security



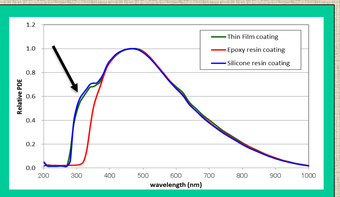


- large soft photon yield per MeV
- high density crystals (stopping power)
- soft photon detection in magnetic fields
- compact design
- high granularity
- non-hygroscopic
- affordable

Detectors requirements:
- High photon yield + good timing resolution (some tens of ns)
- Good energy resolution at low X-rays energy (~ 100 KeV)
- Low cost per channel
- Simple photon readout

Crystals/SIPM arrays properties

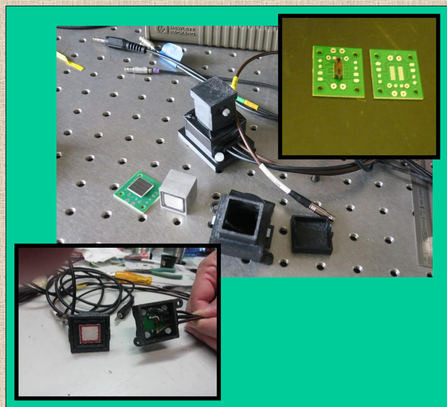
Scintillator	Ce:CAAG	PrLuAG	$LaBr_3$	$CeBr_3$	NAI (Tl)
Density (g/cm3)	6.63	6.73	5.08	5.18	3.67
Light yield (photons/MeV)	57000	22000	75000	47000	38000
Decay time (ns)	88 (91%) 258 (9%)	20	30	25	250
Peak emission (nm)	520	310	360	370	415
Energy resolution (% @ 662 KeV) [PMT]	5.2	4.2	3.0	4.0	7.0
Hygroscopicity	no	no	yes	yes	yes
Melting point ©	1850	2043	783	722	924

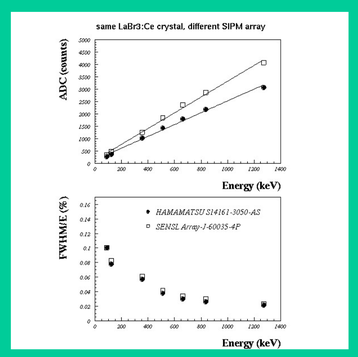


PDEs for used Hamamatsu SIPM array (Silicon window: suitable for UV detection, as in $LaBr_3$:Ce)

	size	Vop	Temp coeff	Peak sensitivity	PDE	Spectral range
Hamamatsu S14161-6050-AS	1 inch	41.1 V	34 mV/C	450 nm	50%	270-900 nm
SENSL Array-J-60035-4P	½ inch	29 V	21.5 mV/C	420	50%	200-900 nm
Advansid NUV3S-4x4TD	½ inch	29.3 V	26 mV/C	420 nm	43%	350-900 nm
Hamamatsu S14161-3050-AS	½ inch	41.1 V	34 mV/C	450 nm	50%	270-900 nm
Hamamatsu S13361-3050-AS	½ inch	53.8 V	60 mV/C	450 nm	35%	320-900 nm

Detectors'assembly & readout

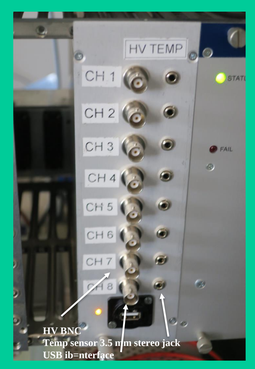


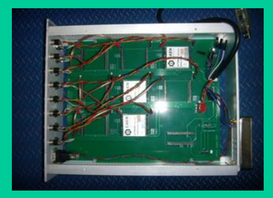


- A simple solution is a crystal read-out by a SiPM array, where single SIPM cells are summed up.
- Detector' holder realized with 3D printer (2 separate pcs. Top: crystal holder, bottom: PCB)
- As LaBr3 crystals + SiPM readout give sizeable signals in the 100 mV range @ Cs^{137} peak, a simple direct FADC readout scheme may be implemented (no preamplifier) .
- Temperature is monitored by a thermistor on the PCB (and corrected online).

- Using the same crystal, different SiPM arrays have been used for readout to allow a strict comparison)
- Resolution @ Cs^{137} peak ~ 3% for both Hamamatsu S14161 and SENSL Array-J -60035 readout
- Good detector linearity (better than 2%)

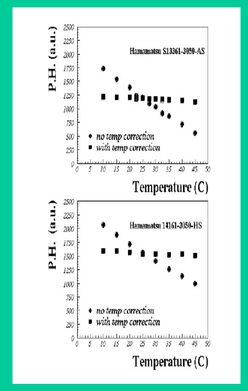
Correction of gain drift with temperature

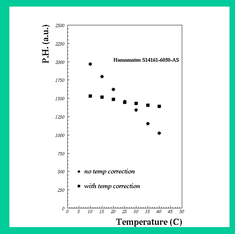




- SIPM gain drift with temperature → needs correction of V_{op}.
- temperature monitor by a TMP37 thermistor
- Custom NIM modules (8 channels) based on CAEN A7585D chips
- Interface with PC either FDTI USB-I2C or Arduino

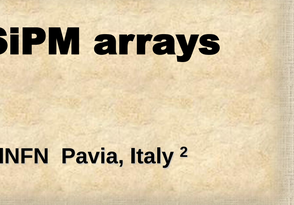
Results on gain drift online correction



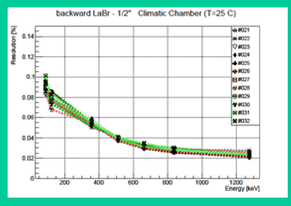


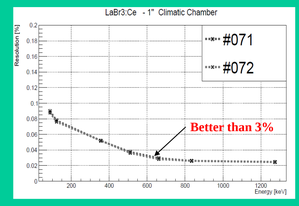
- Tests with a Memmert IPV30 climatic chamber (precision 0.1 ^{0}C between 0-70 ^{0}C)
- In the range 10-40 ^{0}C the effect is reduced from 60% to 6% for ½" detectors and from 50% to 9% for 1"detectors

Test results with Hamamatsu SiPM arrays



Results (linearity,FWHM) for ½" and 1" crystals





- ½" crystals equipped with Hamamatsu S13361-3050 SiPM arrays [same results with S14161-3050-AS-AS], 1" crystals with S14161-6050-AS arrays; temperature correction
- Similar results for resolution between ½" and 1" detectors, but increased risetime for 1" →hybrid ganging for SIPM cells

Conclusions

- ❑ *LaBr3:Ce with SIPM Array and direct FADC readout are promising compact X-rays detectors: good energy resolution and linearity both with ½" and 1" crystals.*
- ❑ *online temperature correction by a custom 8 ch. NIM module*
- ❑ *resolutions around 3% at the Cs^{137} peak: compare well with best $LaBr_3$:Ce detectors read by PMTs available*

References

1. *M. Bonesini et al., JINST 15 (2020) 05, C05065*
2. *C. Pizzolotto et al., Eur.Phys.J.A 56 (2020) 7, 185*
3. *M. Bonesini, PoS EPS-HEP2019 (2020) 132*