Riunione referees Belle2
11 Settembre 2014

- Introduzione

- Update on R&D and upgrade activities
-Future activities
-
- Richieste 2015

C. Cecchi for the ECL-IT group

Introduction

-This R&D has started to demonstrate the feasibility of using pure CsI crystals with APD readout for the BelleII experiment (could be adopted by other experiments).

- **Why APD's and no photopentodes (BelleII proposal)? → mechanics, space, redundancy, cost**

- At the last meeting in May we have presented the progress made in this R&D studying different aspects of two APD's: LAAPD from Hamamatsu and APD from Excelitas.

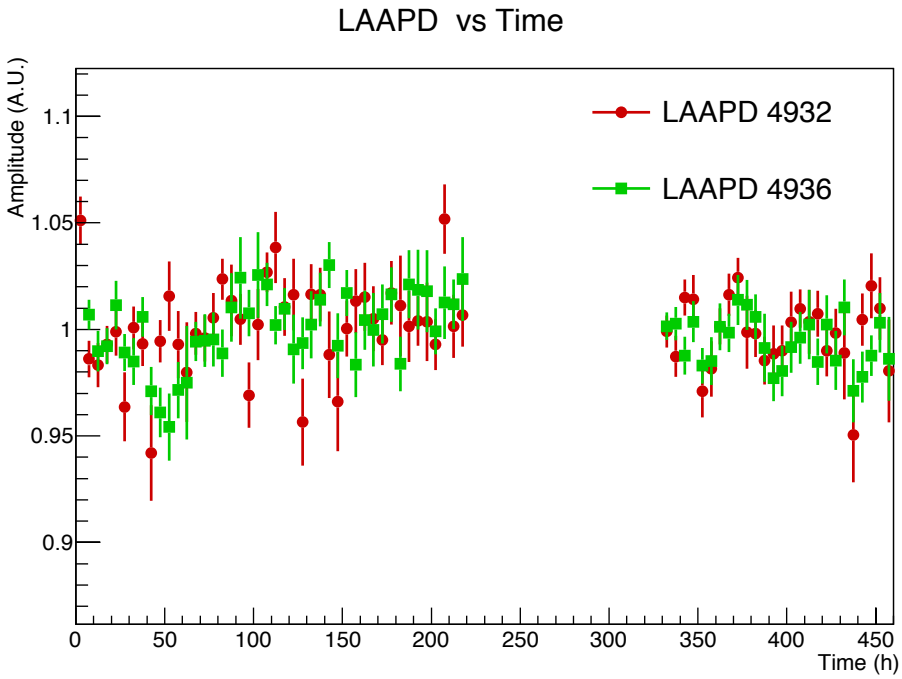
- The study has covered many fundamental points to eventually qualify such photodetectors in order to be used with pure CsI crystals:

  - gain of the APD's for different bias voltages checking that a minimum difference between the applied voltage and the breakdown point was present
  - sum up the signal of the 2(4) LAAPD's (Excelitas) before the shaping to check that a good signal was present
  - shaping of the signal to gain in the ratio S/N and to obtain a good value of the equivalent noise energy (fixed for our caloriemter at 1 MeV)
  - check of the gain variation with the temperature with calibrated sensors

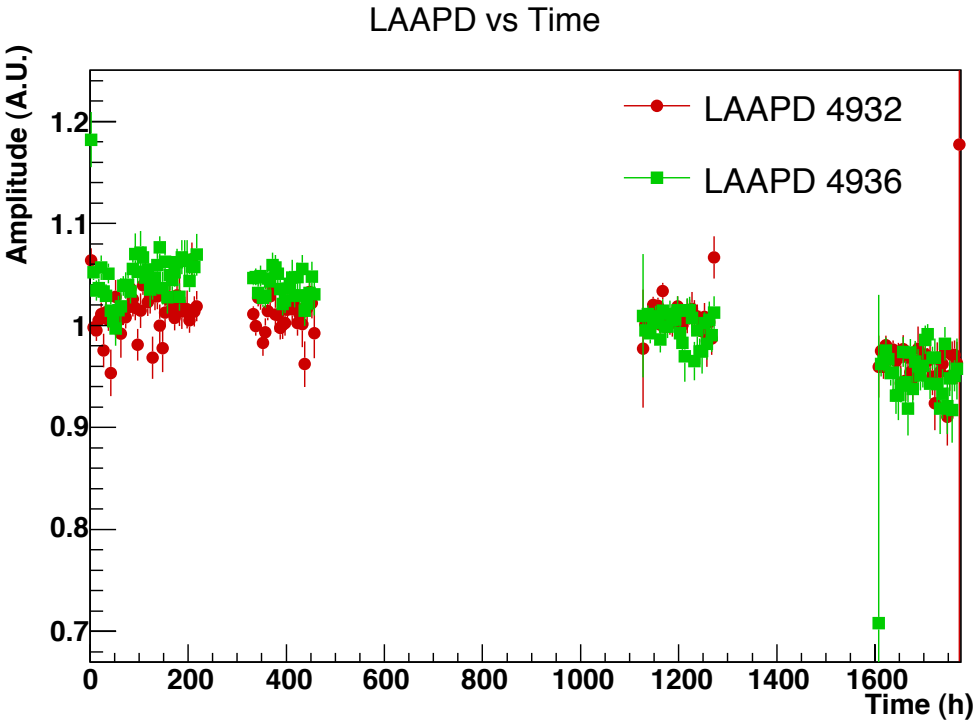
All this has showed good results compatible with our requirements

We have also shown that there is a possibility of readout the pure CsI crystals with two small photopentodes (1" instead of 2" preserving the redundancy)

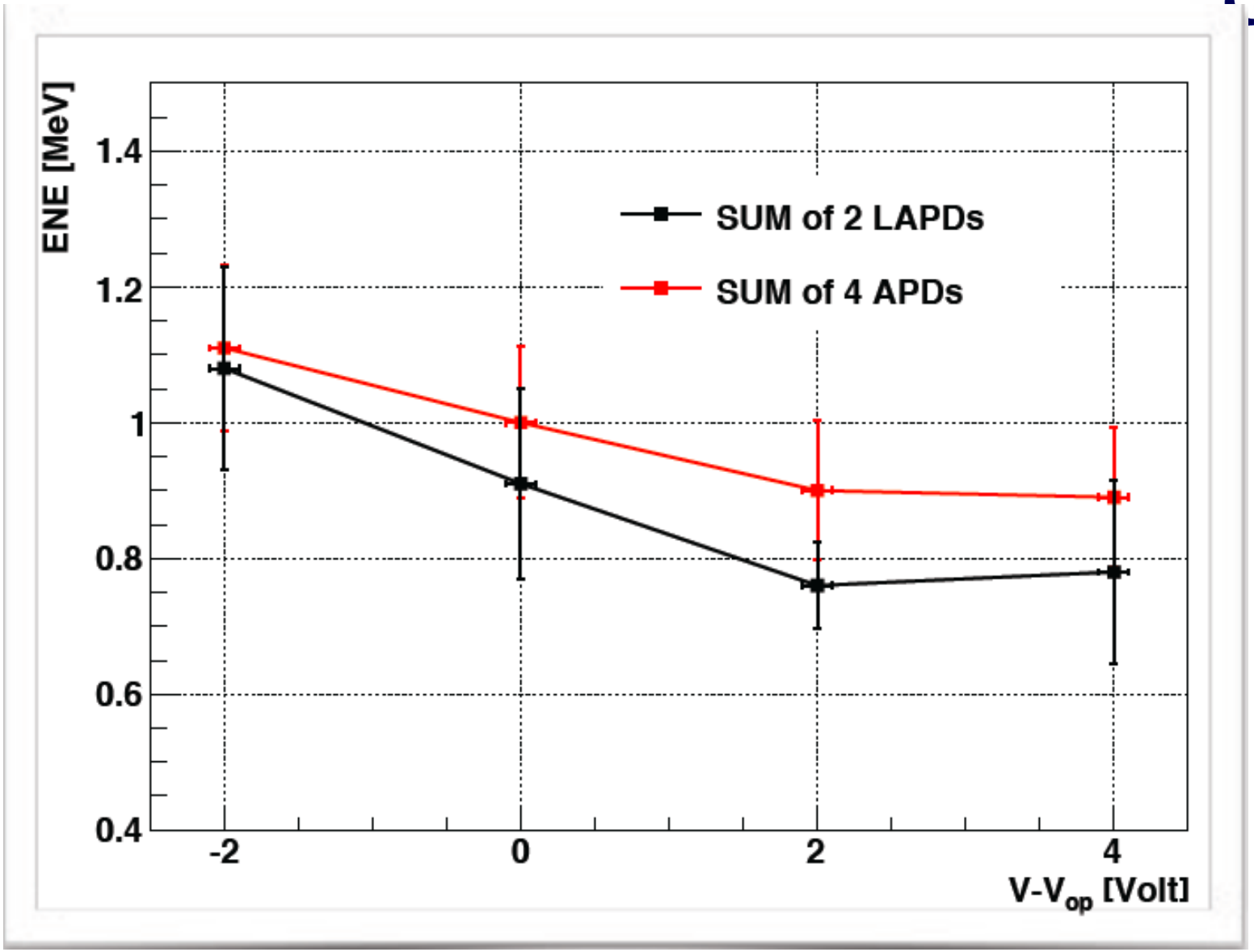
R&D LAAPD: long term stability (NEW)



Stability within 1.4% before a drop we suppose caused by the umidity.
Nitrogen finished during vacation in August!



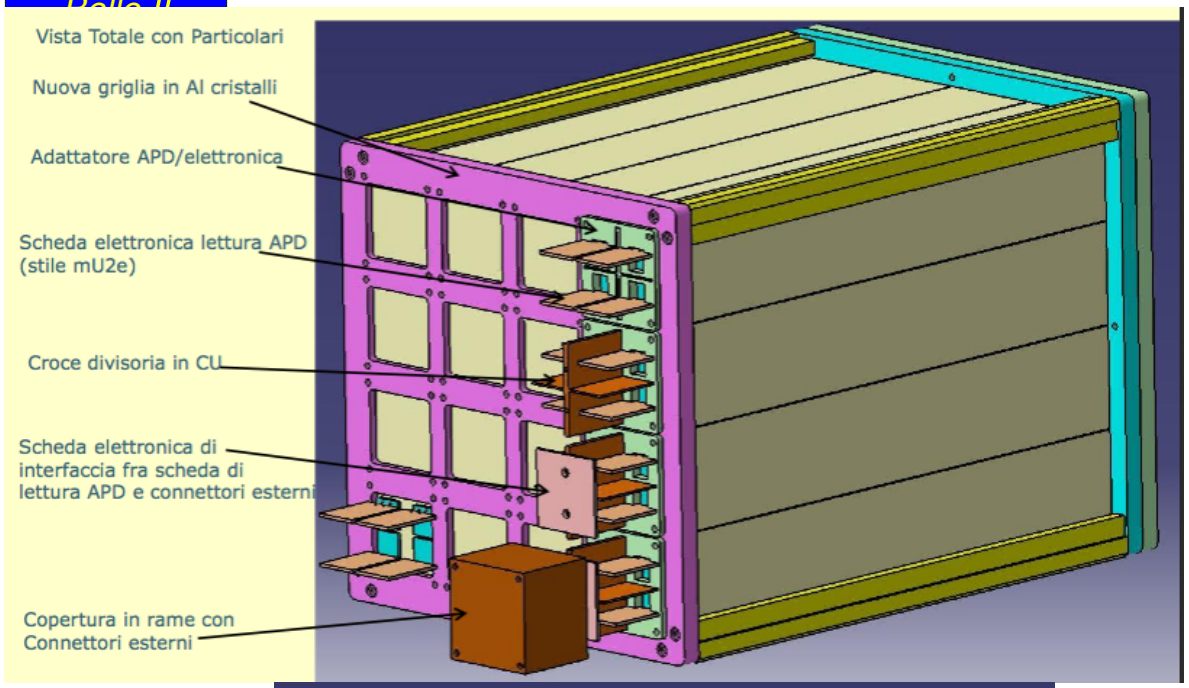
ENE for APD's: final results for the lab measurements

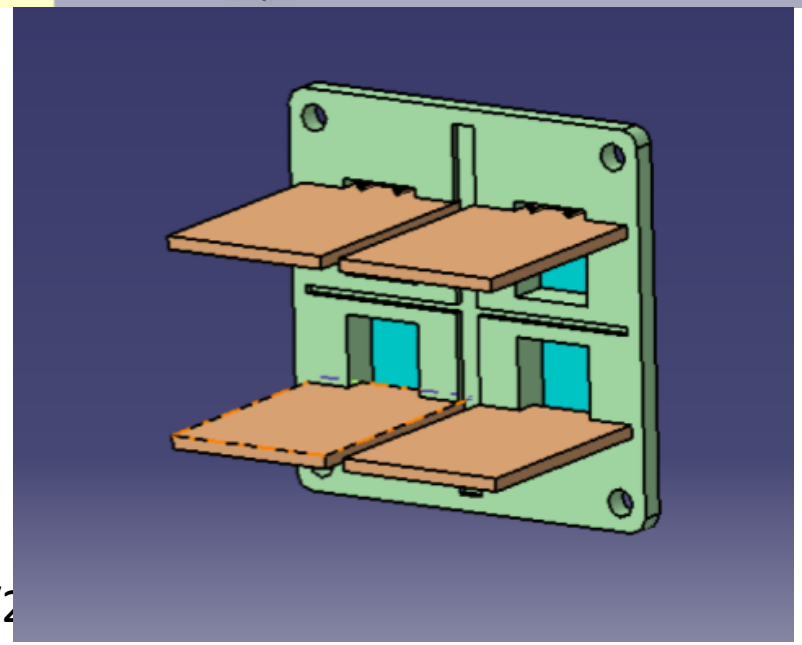


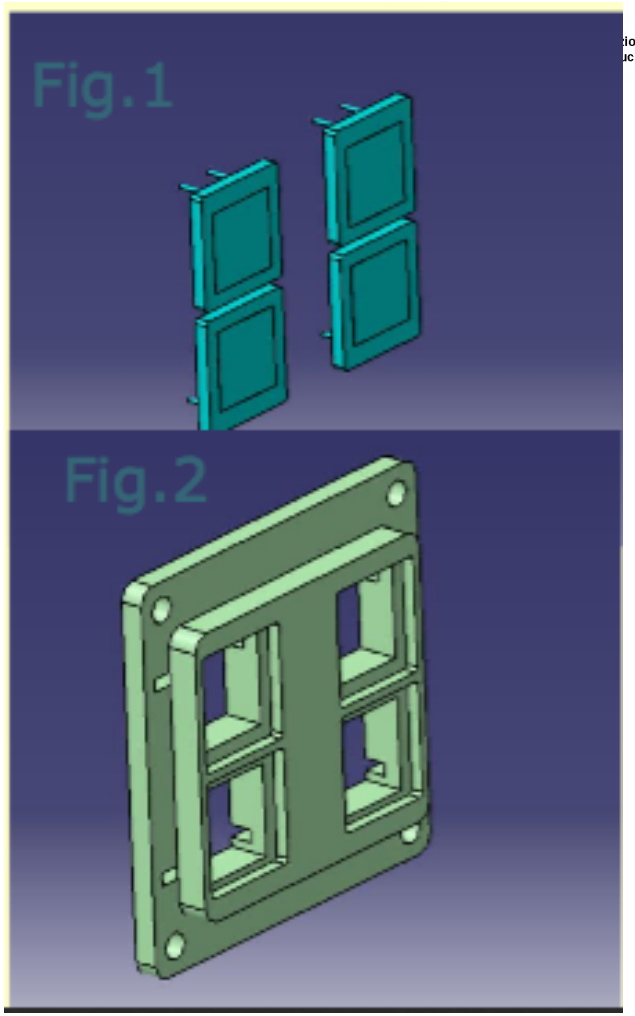
Our requirement is to have ENE< 1MeV

R&D activities for CsI + APD:
We have decided to use the LAAPD from Hamamatsu as photodetectors for the final step:
TEST BEAM BTF Ottobre 2014

End of R&D CsI + APD's: test beam





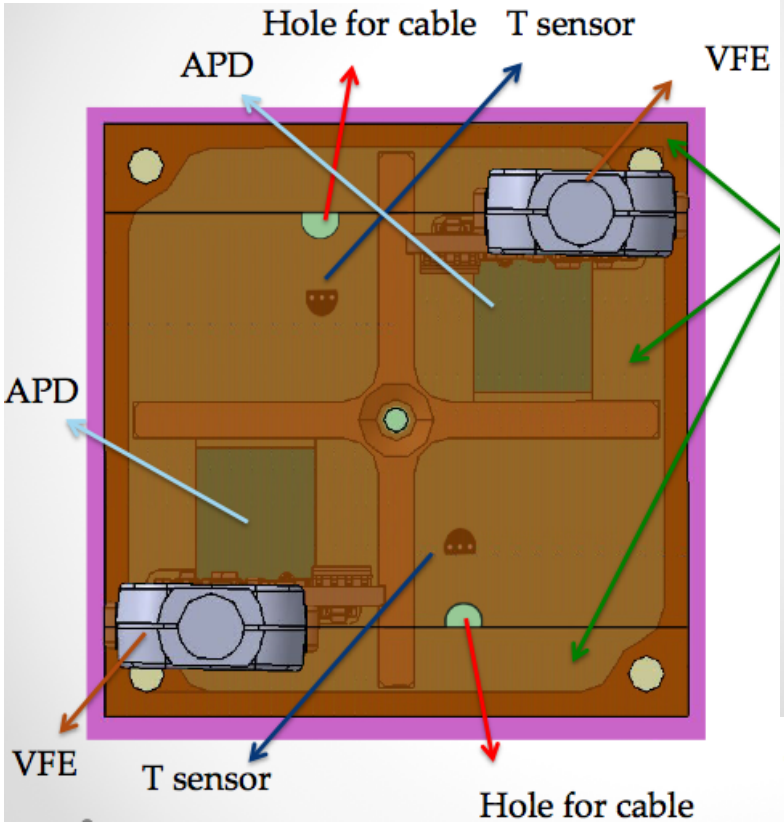


End of R&D pure CsI + APD: TEST BEAM

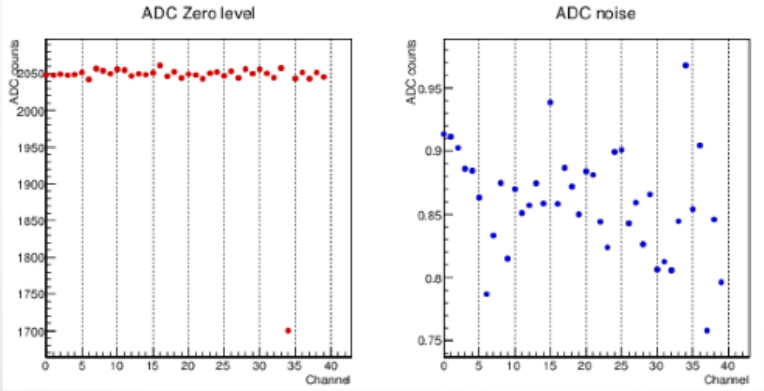
Matrix of 4x4 pure CsI crystals with LAAPD Hamamatsu photosensors.

Material is available and already tested.

To be fixed: temperature sensors have to be placed near APD's, material has been ordered



- 5 V1720 boards with differential inputs
- Each channel test with a very rough setup
  - Single Ended Pulsed signal + a custom board with differential driver
- About 300 triggers for each channel
  - Mean signal used to evaluate the channel functionality
- Baseline and noise w/o any signal at the input:



- All ok except Ch34
  - Too low baseline

(expected value 2048)

Matrix will be assembled and tested with cosmic rays starting from end of September. Move to BTF end of October → data analysis to be completed by end 2014

Summary of what you have seen about the control system (monitoring of volatges, temperatures..)

-We presented the uSOP (**Service Oriented Platform for slow control)**
- Designed as a possible general platform for Belle2 slow-controls
- status of the hardware good: assembly of a prototipe during the summer then test, debugging
- Status of the software good and well progressing

And then….

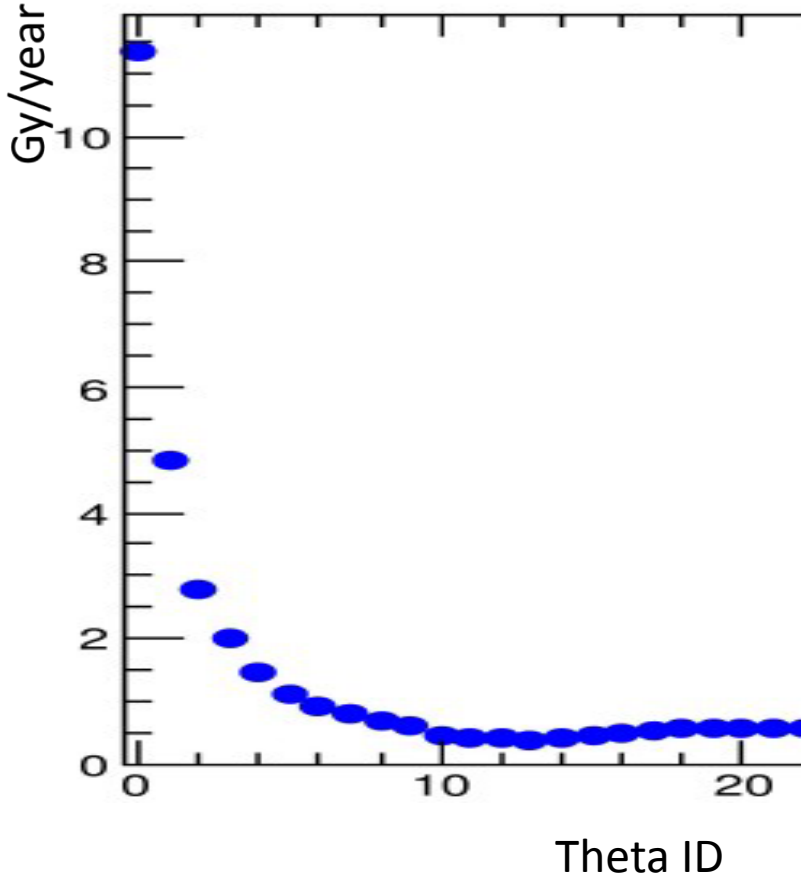
Now we are confident that CsI + APD can make a good calorimeter for the BelleII experiment purposes……

- Still to be checked: radiation hardness of pure CsI crystals, but also of CsI(Tl) (actual ECL Belle) crystals because we want to know if all the ECL has to be replaced or only a part and eventually which part.

- Rad hard of APD's

- ECL group gave us CsI(Tl) crystals from Belle to irradiate them and study their radiation hardness

First and mandatory is to know the level or radiation present in the region of the detector that we are studying, unfortunately this is not really known at the moment!

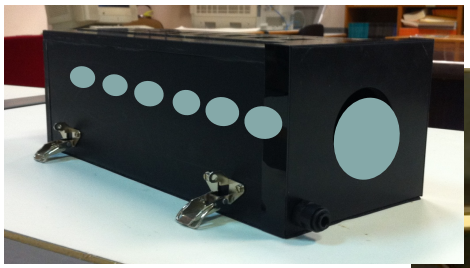


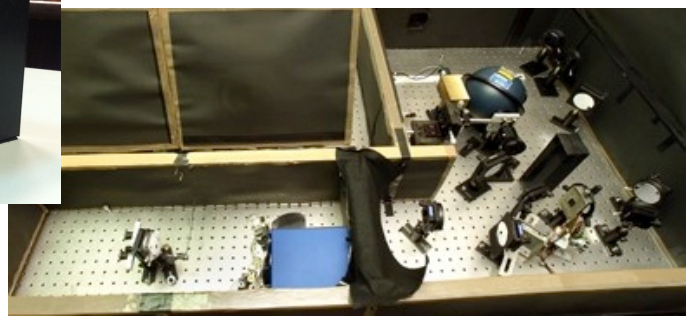
R&D CALLIOPE: activities for BelleII

- **Optical characterization of coupling materials**
- **Transmittance *(long-trasv)* and LY measurements of CsI crystals**

Dry box for LY meas.

Dry box and Lumen spectrophotometer





25m^2 dark room with air conditioning built for CMS-ECAL R&D

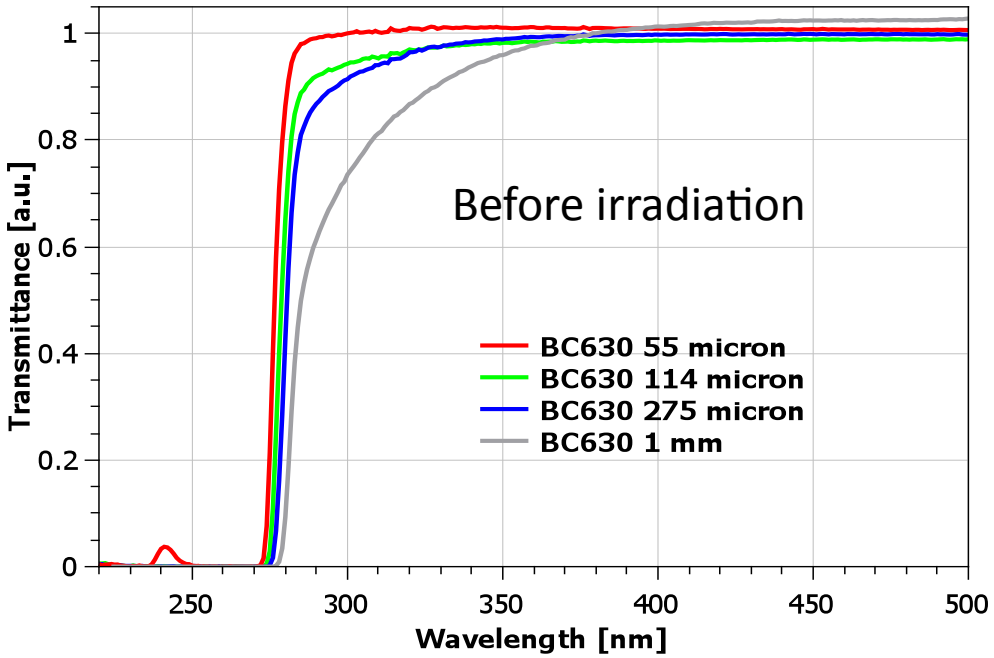
- **R&D on wavelength shifters *(CsI emission toward blue region)***
- **APD irradiation *(gamma, neutrons)***

R&D activities in Italy
Test di qualifica di colle grassi ottici + irraggiamenti

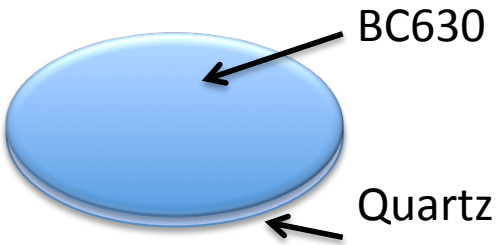
BC630 optical grease

One of the most used optical coupling materials (scintillator-photodetector)

- ✓ High Transmittance , *sample thickness dependent*
- ✓ Abrupt transmittance drop in the UV range (270-280 nm)



Thickness [μ]	Transmittance @ 315nm [a.u.]
55	1.00
114	0.96
275	0.95
680	0.88
1000	0.85

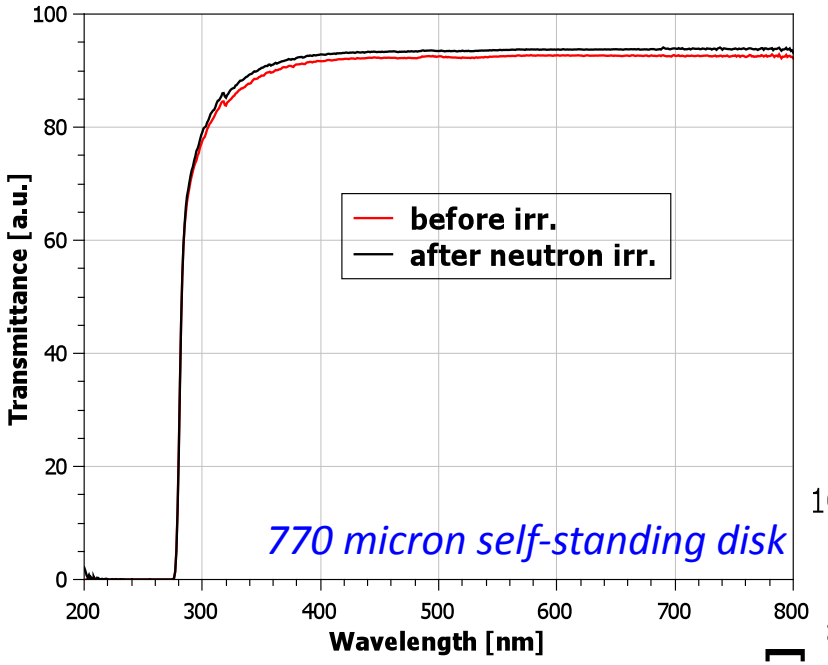


Measurements are made on BC630 applied on quartz substrate

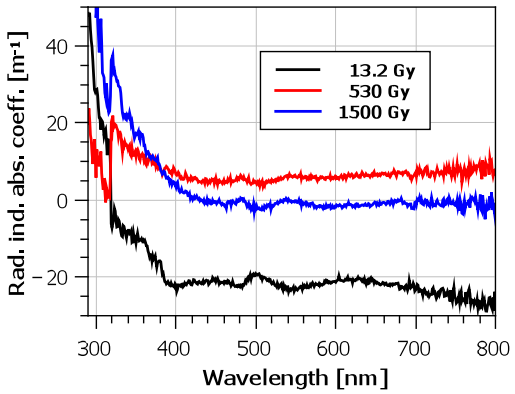
(quartz light attenuation is **always subtracted**)

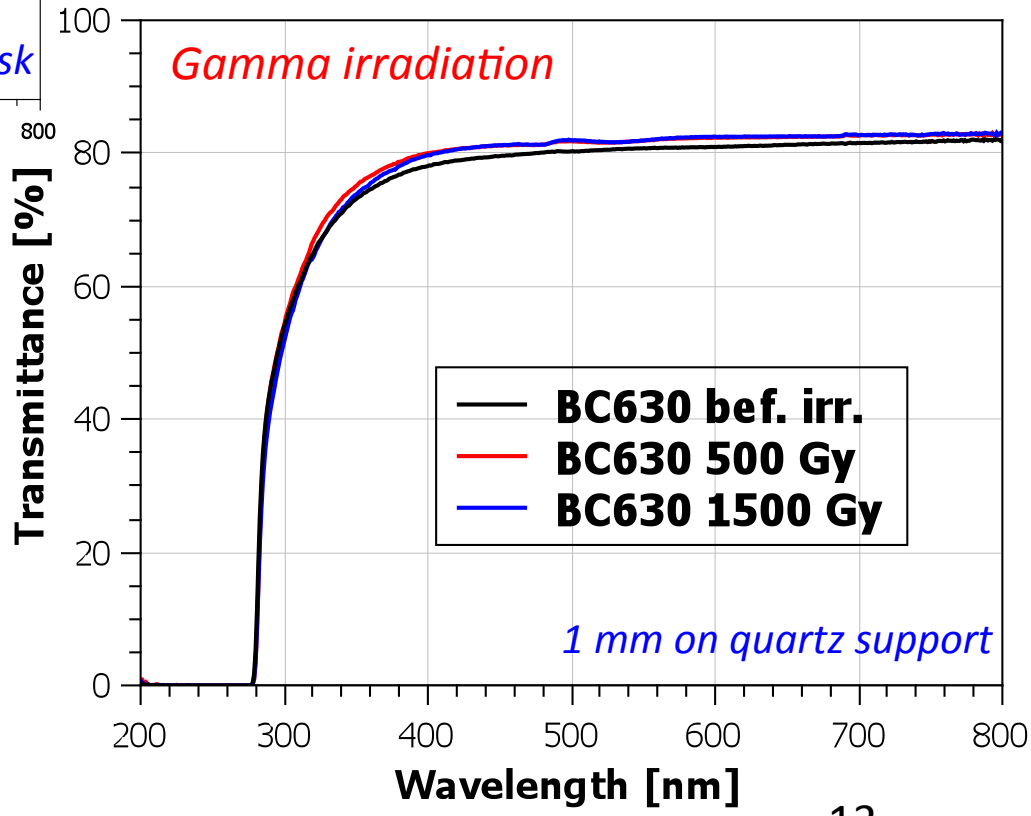
using Perkin-Elmer Lambda 950 spectrophotometer + integrating sphere

BC630 optical grease Gamma and neutron irradiation



Dose/Fluence
13.2 Gy
530 Gy
1500 Gy
$1x10^{13}$ n/cm^2





Radiation hardness study of CsI(Tl) at ENEA Casaccia

BelleII requirements and goal of the study

The dose of the beam induced background in the barrel region has been estimated to be up to 5 rad/yr in the first 2 cm of depth under steady operation at an integrated luminosity of 10^41 cm-2/yr.

- With a large safety margin, the requirement for radiation hardness is set such that the light-output decreases to less than 3%, 10% and 20% at radiation dose of 10, 100 and 1000 rad,(0.1 Gy, 1 Gy and 10 Gy) respectively.

The aim of this work was to verify by means of transmission measurements the radiation induced effects on the bulk and the recovery at room temperature in the dark as well as the LY behaviour under irradiation.

CsI(Tl) crystal measurements

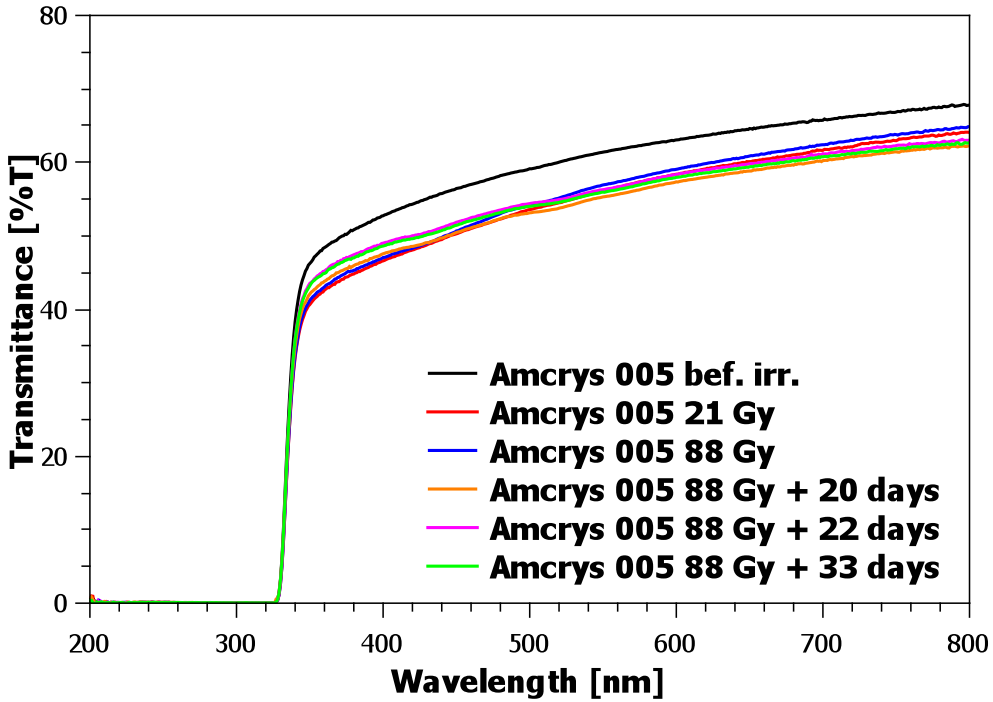
Two samples of large CsI(Tl) crystals came from Amcrys (Karchov, Ukraine) through Naples group, 5x5 cm^2 cross section, 30 cm long (Belle II ECL standard size)

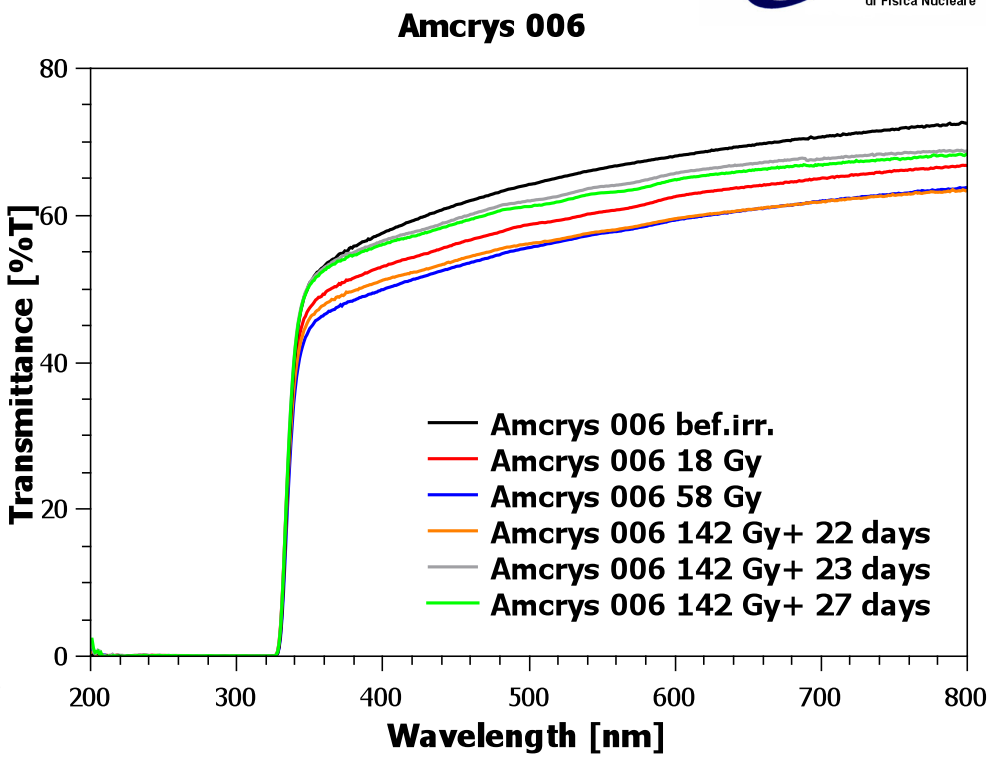
Transmittance and LY measurements were performed in the dark room

Crystals irradiated and stored in dry air atmosphere and kept in the dark

Transmittance spectra of CsI:Tl AM005 and AM006

%T error: ± 2%





after irradiation:

- transmittance decreases in the whole range
- no evidence of Tl absorption peaks (300-600 nm)
- partial recovery after the end of irradiation

Crystals stored in dry air atmosphere

Radiation damage evaluation of Cs:Tl

Gamma irradiation tests:

Dose rate: 5 Gy_{air}/h

Total absorbed dose: up to 88 Gy (Amcrys 005)

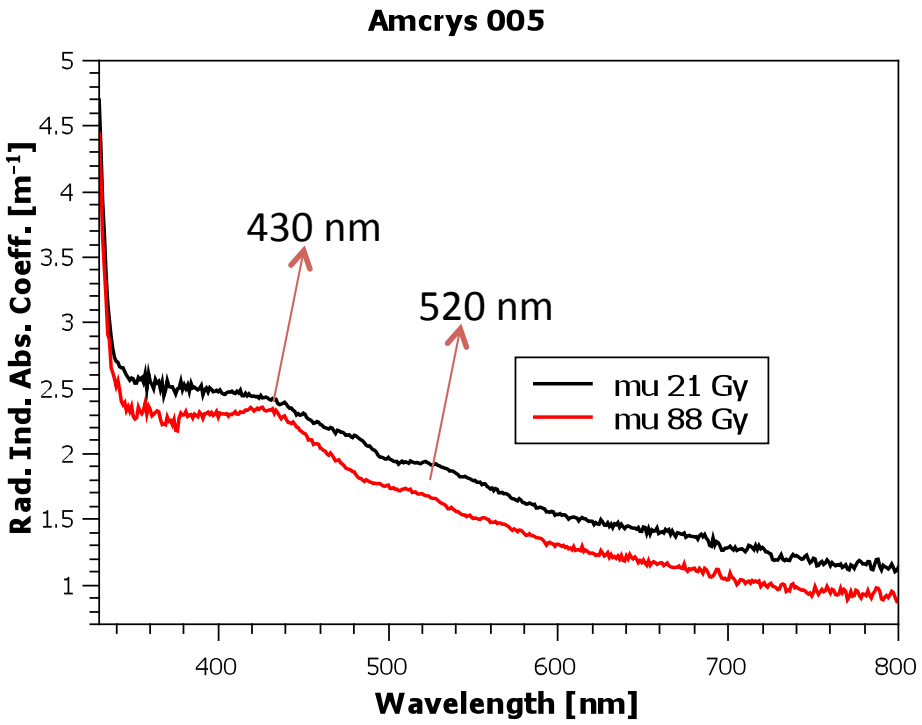
up to 142 Gy (Amcrys 006)

Irradiation conditions: in Argon atm., at RT, keeping the crystals in the dark

Radiation Induced Absorption Coefficent (μ)

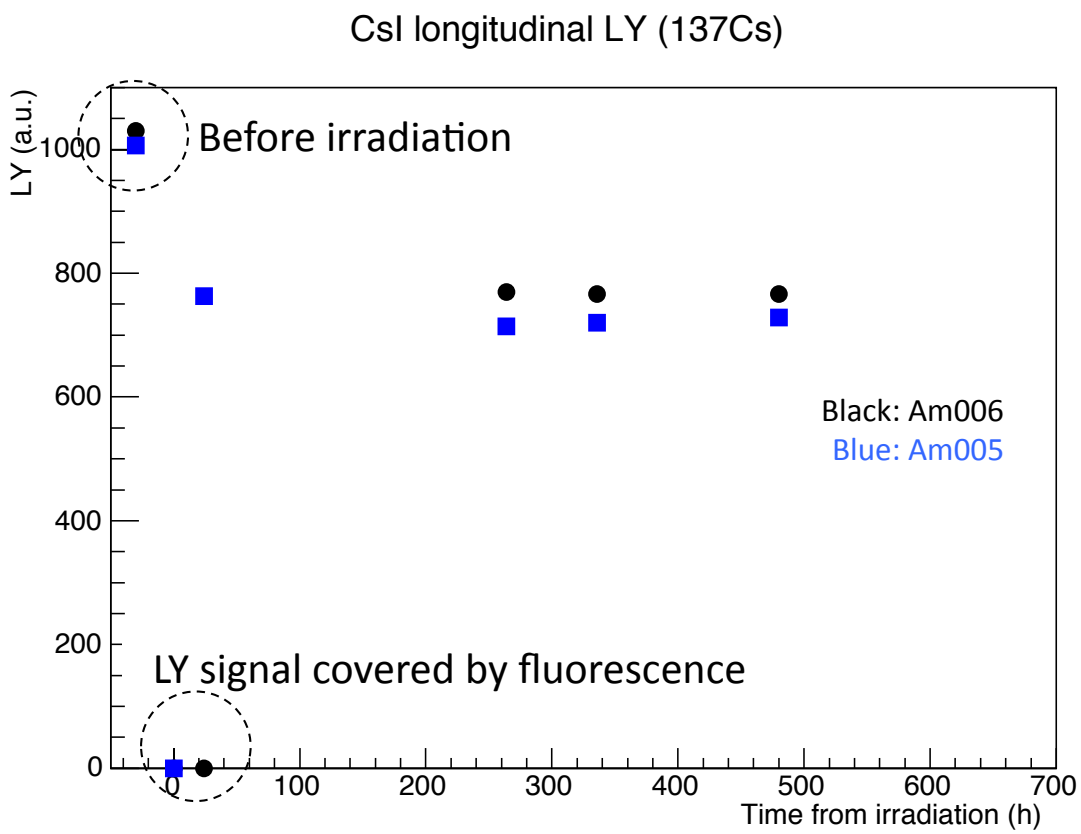
$$\mu = \frac{1}{d}\ln\left(\frac{T_0}{T}\right)$$

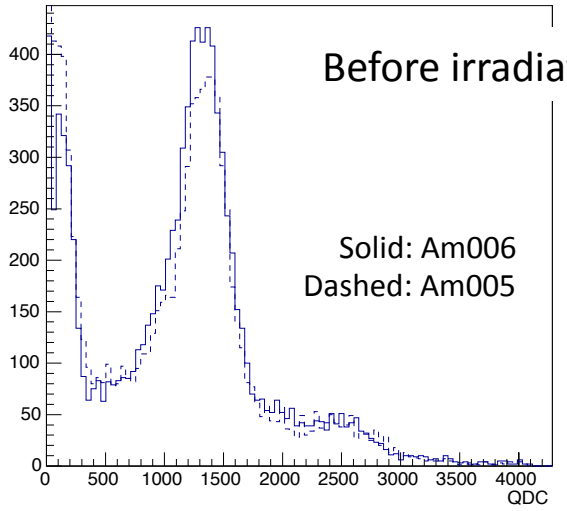
used to quantify color center formation due to ionizing radiation

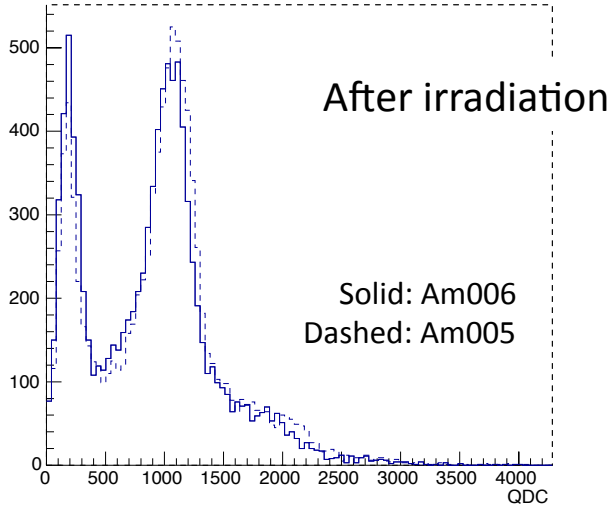


CsI(Tl) Amcrys LY pre-post irradiation

- Two CsI(Tl) samples irradiated up to 142 Gy TID with gammas
- LY measured with 137Cs source, PMT+QDC, AC-coupling







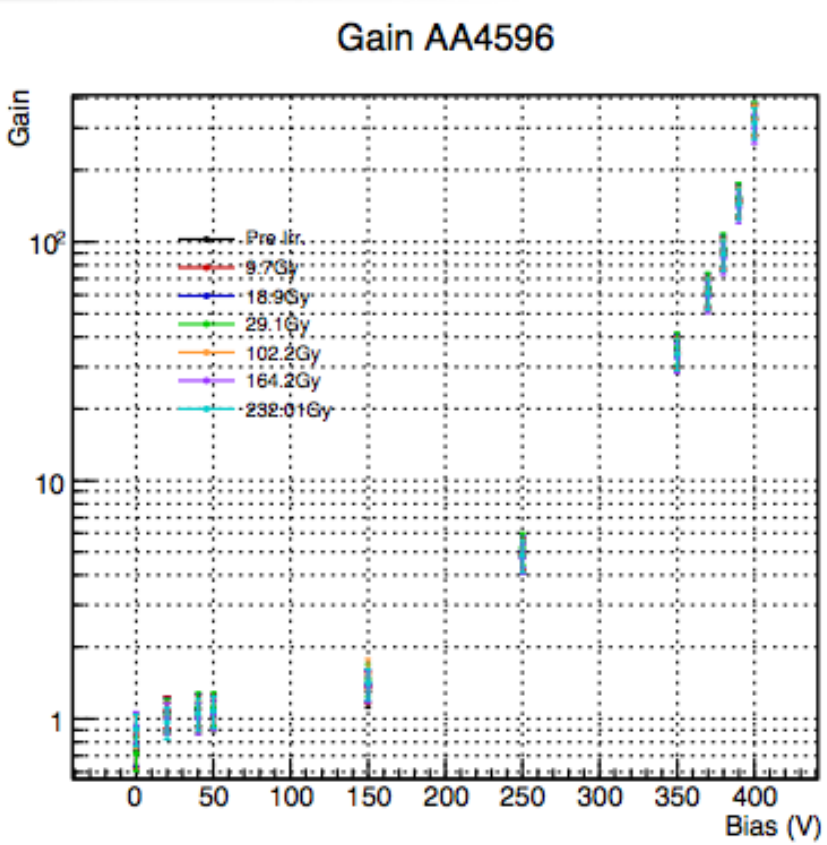
Caveat: LY signal after irradiation could be reduced by unpredicted long term fluorescence due to AC-coupling to FEE

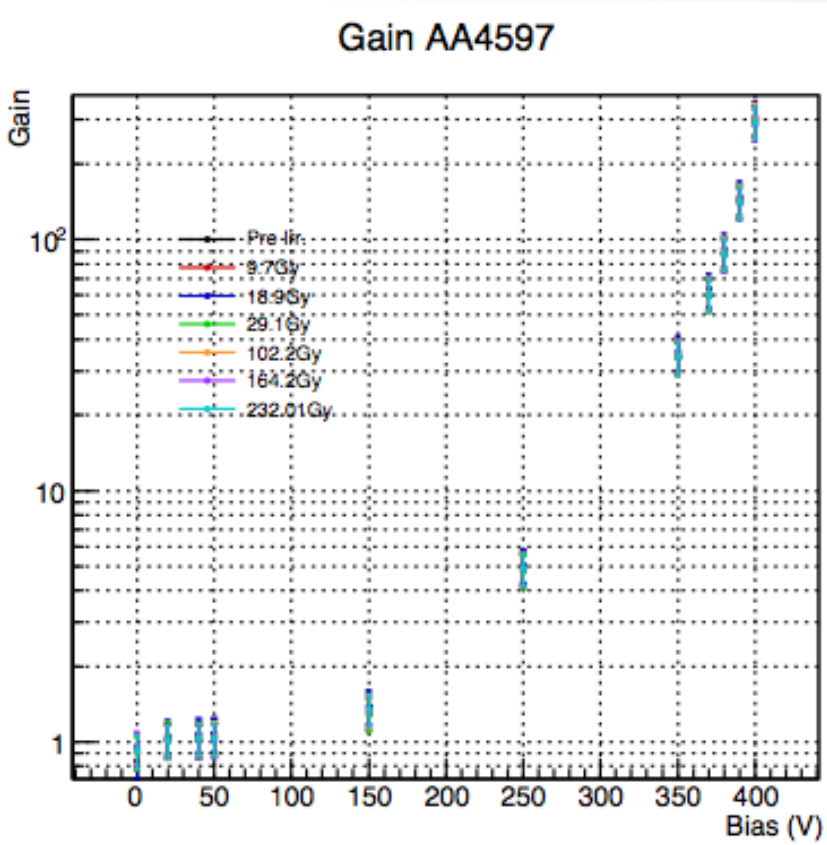
Radiation hardness study of APD's at ENEA Casaccia

LAAPD gamma irradiation

- 2 LAAPD irradiated with γ
  - Dose rate 4.52Gy/h
- Expected dose rate at Belle2 ~13Gy/year
- Measured points:
  - PreIrr
  - 9.7Gy
  - 18.9Gy
  - 29.1Gy
  - 102.2Gy
  - 164.2Gy
  - 232Gy
- 4 dark current measurements after irradiation for recovery studies

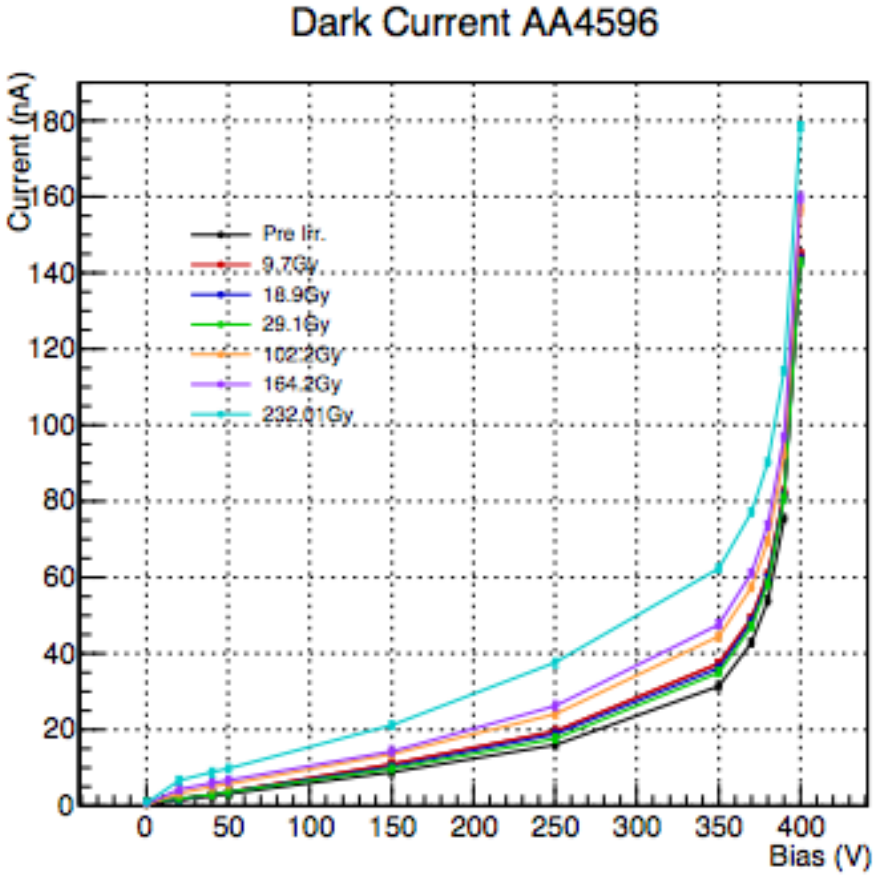
LAAPD gamma irradiation: GAIN

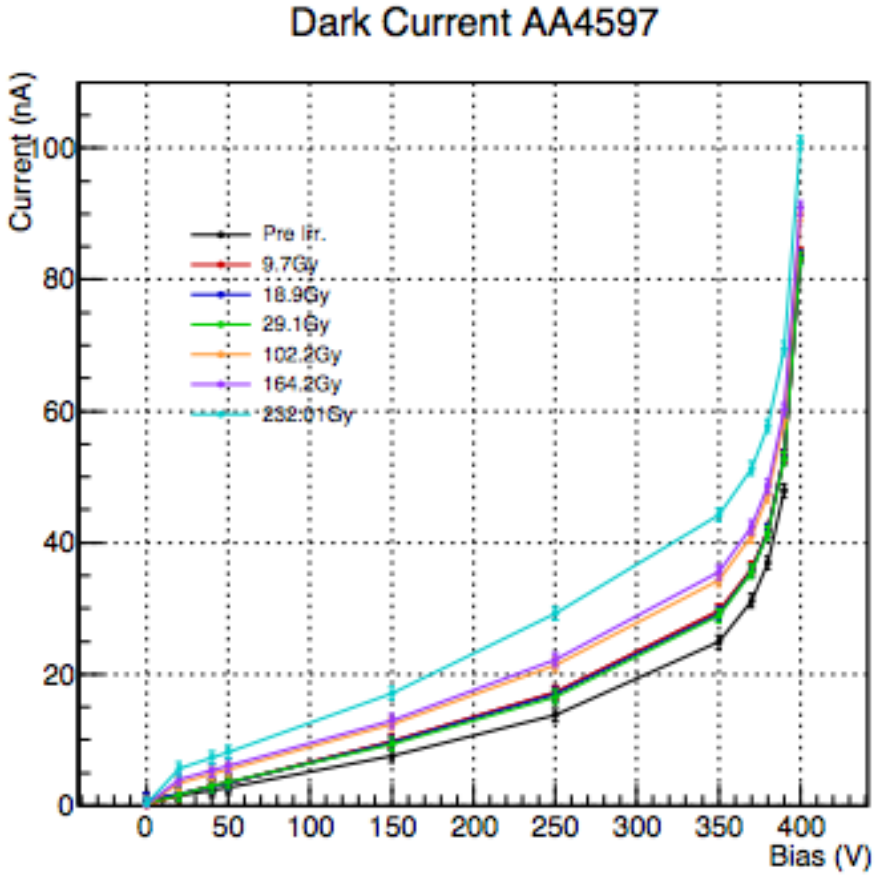




- No visible effects on Gain

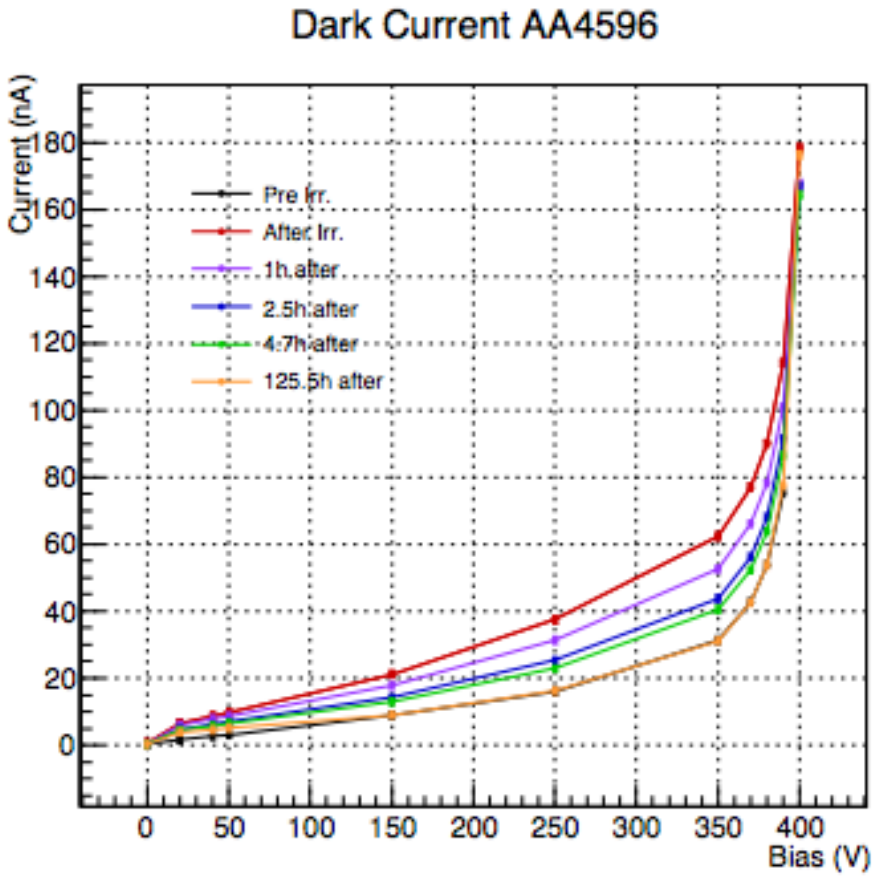
LAAPD gamma irradiation: Dark Current

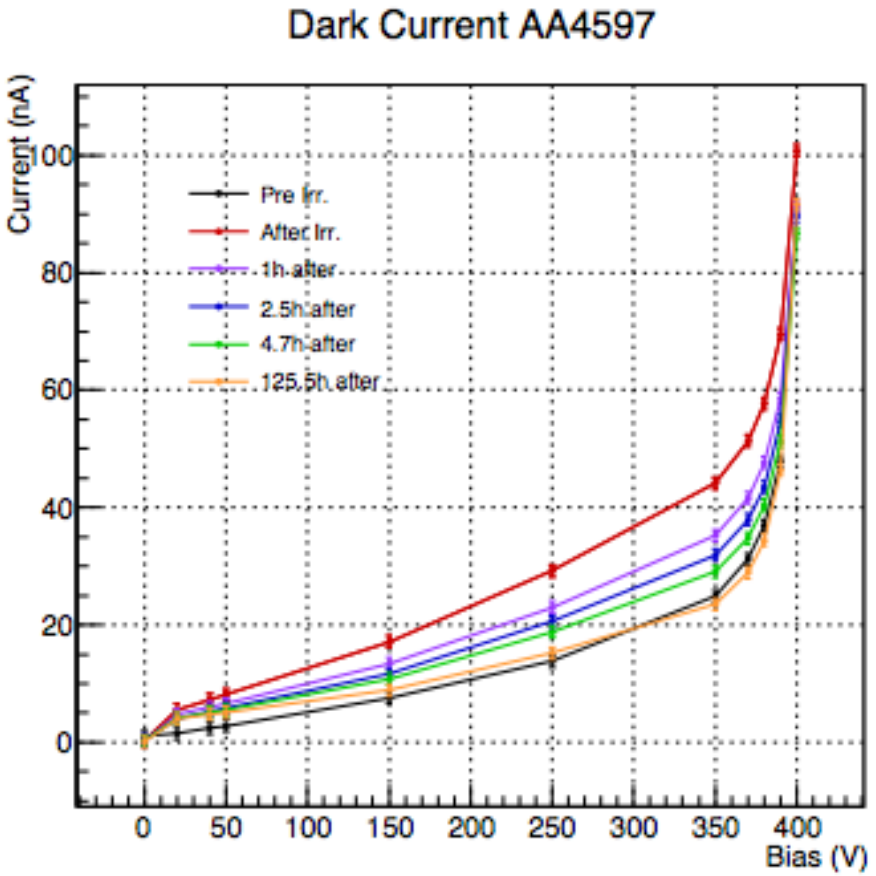




- Dark current increase of a value between 25% and 40% in the working region @ 164Gy (~10y of BelleII)
- @ 232Gy the dark current increase of a value between 50% and 80%

LAAPD gamma irradiation: Recovery of DC





Attention! Expected dose at BelleII: 13 Gy/year

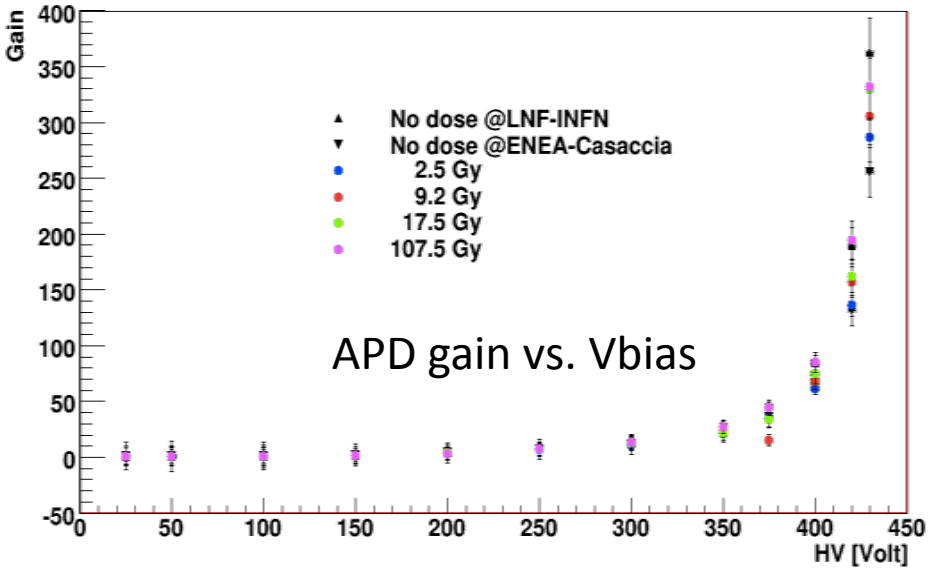
New campaign next week at the same dose per day expected at the experiment.
See if increasing of DC at this doses is immediately recovered.
NEUTRONS to be done

Excelitas APD gamma and neutron irradiation

Two Excelitas APDs were irradiated with photons at Calliope:

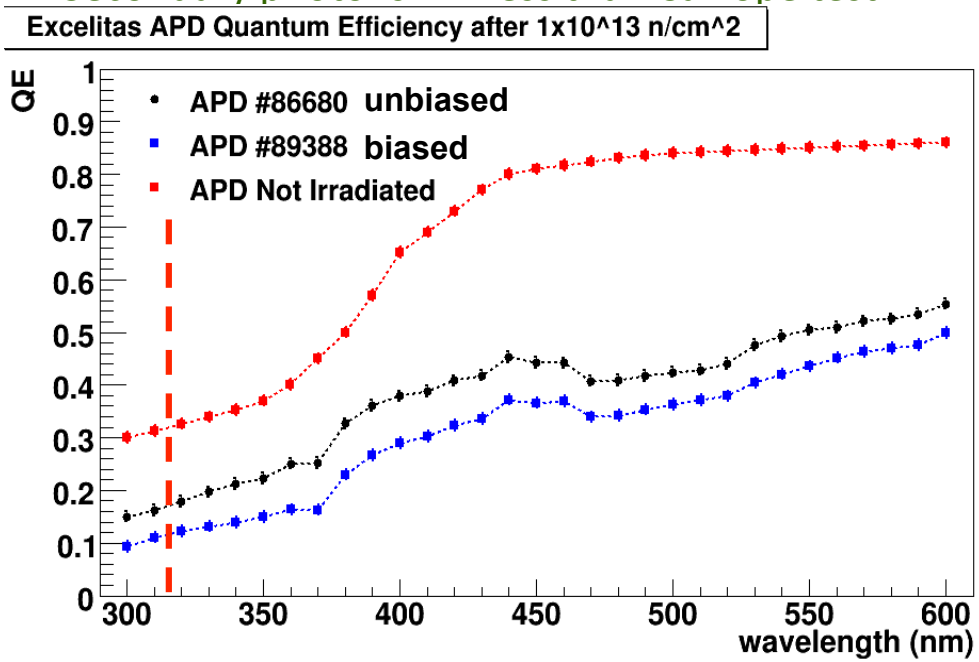
- Total Ionizing Dose 108 Gy
- Gain measurements with increasing dose, temperature correction applied

No significant effect of TID on APD gain



The same samples were irradiated with fast (0.1-10 MeV) neutrons at Tapiro, up to a fluence of $1x10^{13}$ n/cm^2 (10 years x5 of B2)

- One device was biased during irradiation
- Secondary photons TID less than Calliope test



Excelitas APDs show a significant loss in Quantum Efficiency after $1x10^{13}$ n/cm^2 :

- Main component is probably due to damage to resin cover
- Slight difference could be due to biasing during irradiation (silicon oxides damage)

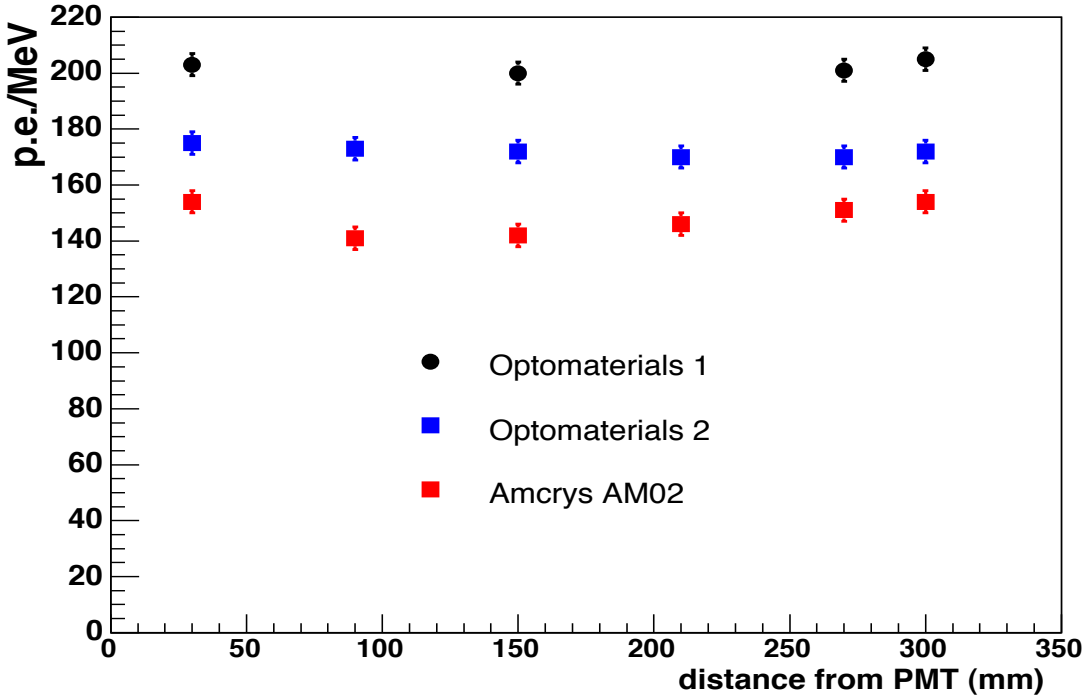
Qualification of pure CsI crystals from Optomaterials at ENEA Casaccia

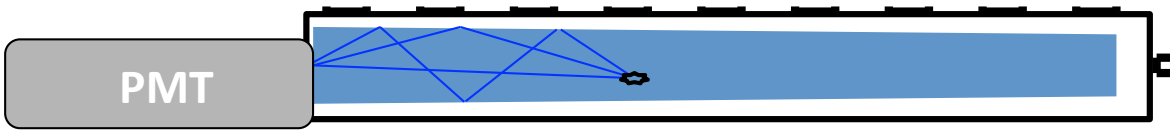
Pure CsI Optomaterials: Light Yield

Optomaterials show the best LY among the considered samples:

- both samples have higher LY than Amcrys
- Opto and Amcrys show homogeneous LY along crystal depth (30 cm)

SICCAS induced scintillation is covered by background





Longitudinal LY variation:
Optomaterials < 5%
Amcrys < 10%

Measured without wrapping and without optical grease

Conclusions on irradiation test

- ✓ **Optical couplings**: BC630 optical grease suitable for Belle II (scintillation wavelength and radiation environment)
- ✓ **CsI:** Optomaterials crystals very promising before irradiation (LY, Transmittance)
- ✓ **CsI(Tl):** radiation damage by T and LY measurements
- ✓ **APDs**: Excelitas show significant damage by neutrons (Belle II 10 years x 5)

R&D activities
Piani futuri a breve e medio termine
Irraggiamenti
Studio livelli radiazione
Simulazione dettagliata e performance ECL

ECL FWD upgrade: futuro prossimo

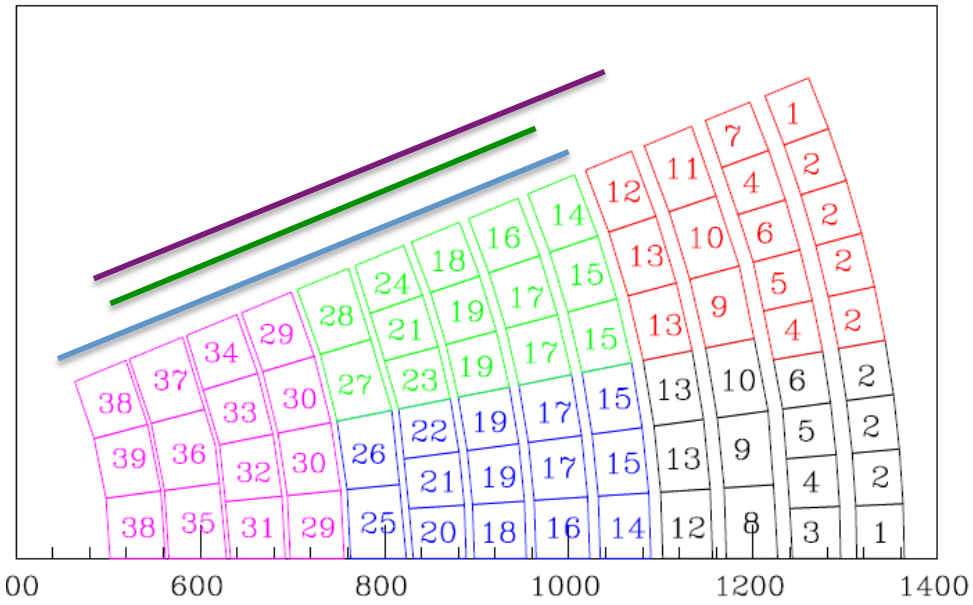
- 50% del finanziamento per l'upgrade dell'intero calorimetro (Canada) non è stato approvato, richiesta nuova tra due anni
- Richieste da parte dei gruppi di Novosibirsk e Giapponesi sono in corso
- Un proposal dedicato all'upgrade di ECL FWD è in fase di scrittura da utilizzare come documento per le richieste di fondi alle agenzie finanziatrici

- I NOSTRI PIANI LEGATI ALLE RICHIESTE DEL 2015 NON CAMBIANO!

- Optomaterials e la qualifica della loro produzione di cristalli è di fondamentale importanza non solo per il calorimetro di BelleII.

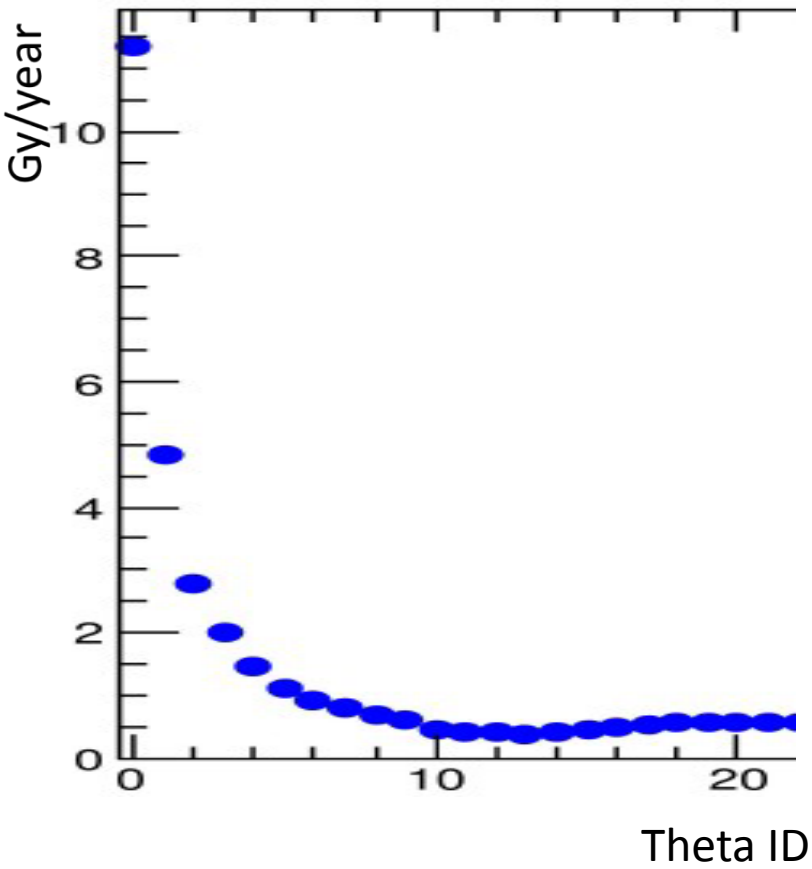
- Uno studio più approfondito per l'upgrade è assolutamente necessario, non è sufficiente quanto è stato fatto per il TDR → da mettere nel proposal

Replacement of the rings: complete or partial?



a) From 0 to 8
b) From 1 to 8
c) From 1 to 9

a) 672 pure CsI + 480 CsI(Tl)
b) 48 CsI(Tl) + 624 pure CsI + 480 CsI(Tl)
c) 48(?) + 720 pure CsI + 384 CsI(Tl) (exclude 1st layer from trigger and maintain same number of trigger cells)



ECL FWD upgrade: attività 2015 (irraggiamenti e test)

- **Studio dei livelli di radiazione nel FWD sono fondamentali per poter organizzare una corretta campagna di irraggiamenti alle dosi corrette.**

- **CsI**: LY and longitudinal transmittance measurements after irradiation
- **CsI(Tl) Belle**: characterization after irradiation and recovery of 3 crystals
  - by cosmic-rays set-up
  - by T and LY measurements
  - as reference
- CsI & CsI(Tl): radiation damage and recovery by means of optical characterization and LY measurements.
- AMCRYS + Optomaterials crystals will be compared

- Neutron irradiation on APD's and quantum efficiency test

ECL FWD upgrade: 2015 (software and simulation)

- Studio dei livelli di radiazione
- simulazioni sono in corso con diverse tipologie di shielding
- non esistono simulazioni per la parte di radiazione durante l'iniezione della macchina

- Una volta noti i livelli di radiazione è necessario fare uno studio di quali ring sono a rischio danneggiamento → studiare la risoluzione del calorimetro in funzione della variazione di Light Yield per ogni ring → estrapolare il minimo numero di ring necessari per mantenere le performance del calorimetro richieste.
- Studio della risposta del rivelatore con eventi di fisica (ricostruzione pi zero e poi canali di decadimento importanti per ECL) prima in funzione della variazione del LY con la radiazione e poi in funzione della sostituzione dei ring danneggiati di CsI(Tl) con CsI puro.

- software e tools tutto da implementare in full sim, non esiste una fast sim in BelleII, stiamo mettendo su un gruppo di lavoro su questo argomento.

Richieste

Anticipi 2015

SJ avanzato 14Keuro (PG) + 7Keuro (NA) consumi
costruzione apparati (56Keuro) non utilizzati
TOT = 77 Keuro

→ vorremmo tenerli per acquistare uno spettrofluorimetro per la qualifica dei cristalli + acquisto cristalli richiesti per il 2015

Diventa di fondamentale importanza dopo il primo test di produzione di Optomaterials che ha avuto esito assolutamente positivo e quindi molto promettente.

Spettrofluorimetro 32Keuro + IVA = 38 Keuro (contributo da Roma1 DOT 3 Keuro)
Cristalli Optomaterials 42 Keuro

TOT = 80 Keuro

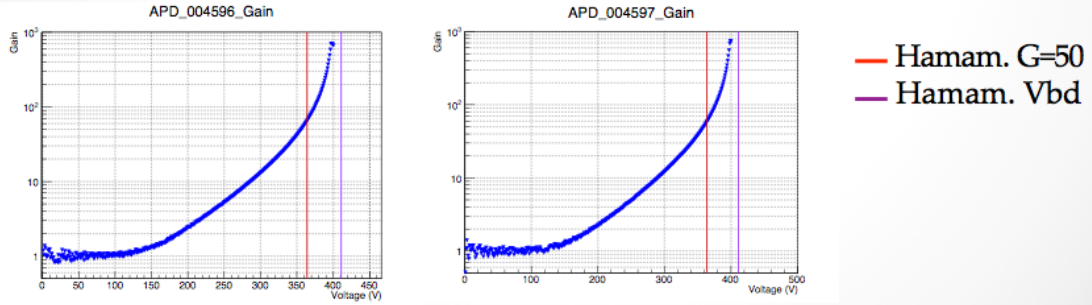
Sede	Capitolo	Categoria	Descrizione	Richiesta	Richiesta SJ	Anticipabile 2014?	Commenti
LNF	missioni	A	Partecipazione workshop computing/software Belle2 (2 persone * 2 workshop)	6			ECL reconstruction + e-ID
LNF	missioni	A	ECL software meeting Italia (3 persone)	3			
LNF	missioni	A	Workshop Belle2-ECL (7 pers x 1 mtg)	3.5			
LNF	missioni	A	ECL Italia meeting	5			7 persone
LNF	missioni	D	Istallazione ECL a KEK (2 m.u.)	12			2 m.u.
LNF	missioni	D	Spostamento, assemblaggio, test inizio costruzione ECL a KEK		6		SJ approvazione upgrade
LNF	consumo	A	Termostatazione e regolazione umidita' scatola nera	5			
LNF	consumo	A	2-3 cristalli e APD di lettura				Richiesta a PG
LNF	consumo	A	Tooling per assemblaggio, meccanica	5			
NA	missioni	A	ECL Italia meeting	7			4/5 meeting anno per 6 persone
NA	missioni	A	meeting sviluppo software ECL in Italia (1 persona)	1			
NA	missioni	D	installazione ECL a KEK (2 m.u.)	12			2 m.u.
NA	missioni	A	Workshop Belle2-ECL (6 persone x 1 meeting)	3			
NA	consumo	A	PCB per sviluppo versione 2 prototipo uSOP (5 esemplari)	3.5			
NA	consumo	A	componenti per prototipi uSOP versione 2	6			
NA	consumo	A	montaggio e radiografie giunti saldature	5			
NA	consumo	A	PCB per integrazione ADC, porte I/O basata su IRQ, definizione fattori di forma scheda e crate(5 esemplari)	5			
NA	consumo	A	componenti per integrazione ADC, porte, e definizione fattori forma	12			
NA	consumo	A	montaggio e radiografie giunti saldature	6			
NA	consumo	A	realizzazione di una catena di acquisizione per test uSOP (materiali per supporti, preamp, shapers, sonde, sorgenti led)	10			
NA	consumo	A	consumo per stazione di test con cosmici	5			
PG	missioni	A	Viaggi produttori cristalli	5			2 viaggi Cina + Ucraina + viaggi Optomaterials qualificazione ditta
PG	missioni	A	Partecipazione workshop computing/software	6			responsabilità software calibrazione ECL
PG	missioni	A	Incontri di lavoro per software/ricostruzione/fisica	2			incontri tra italiani 4/anno
PG	missioni	A	ECL Italia meeting	4			
PG	missioni	A	Missioni a LNF per test, assemblaggio e meccanica	3			
PG	missioni	C	Coordinatore ECL	5			
PG	missioni	D	Spostamento, assemblaggio, test inizio costruzione ECL a KEK		6		1 m.u. SJ
PG	missioni	D	Refurbishement ECL Barrel + endcap	12			2.m.u.
PG	missioni	A	workshop Belle2-ECL (2 pers x 2 mtg)	3.5			
PG	consumo	A	Cristalli irraggiamento SICCAS + AMCRYS	20			
PG	consumo	A	Cristalli irraggiamento + qualifica Optomaterials	30		Yes	
PG	consumo	A	APD per studi di rad hard	10		Yes	
PG	consumo	A	Tooling per assemblaggio, meccanica	5			
PG	apparati	A	Inizio costruzione ECL		55		SJ
PG	consumo	A	struttura meccanica x test su cristalli costruzione		30		SJ
PG	trasporti	A	spedizione primo assemblaggio ECL		10		SJ
RM1. DTZ	missioni	A	Contatti produttori cristalli italiani 3 viaggi 2 pers	3			cntatti con produttori e tra le sedi
RM1. DTZ	missioni	A	workshop Belle2-ECL (2 pers x 2 mtg)	3.5			
RM1. DTZ	missioni	A	ECL Italia meeting	4			
RM1. DTZ	consumo	A	Irraggiamenti gamma e neutroni su APD e cristalli	20			
RM1. DTZ	consumo	A	Materiale per linee gas/ elettronica/ ottica	7.5			bombole gas, contenitori a tenuta gas,cavetteria per set-up irrag, WLS, ottica
RM1. DTZ	inventario	A	Spettrofluorimetro	35		Yes	caratterizzazione fotoluminescenza cristalli pre- e post-irraggiamento
RM1. DTZ	inventario	A	Oscilloscopio portatile per setup in impianti di irraggiamento	2			
RM1. DTZ	inventario	A	Crate VME	3			
RM3	missioni	A	workshop Belle2-ECL (2 pers x 2 mtg) e Belle2 meeting italiano	4			
RM3	missioni	D	Refurbishement ECL Barrel + endcap	12			
RM3	missioni	D	assemblaggio modulo KEK	6			
RM3	missioni	A	ECL software meetings	4			
RM3	inventario	A	impulsatore per test pre-amp	10			
RM3	Consumo	A	consumo per ulteriore sviluppo pre-amp	22			

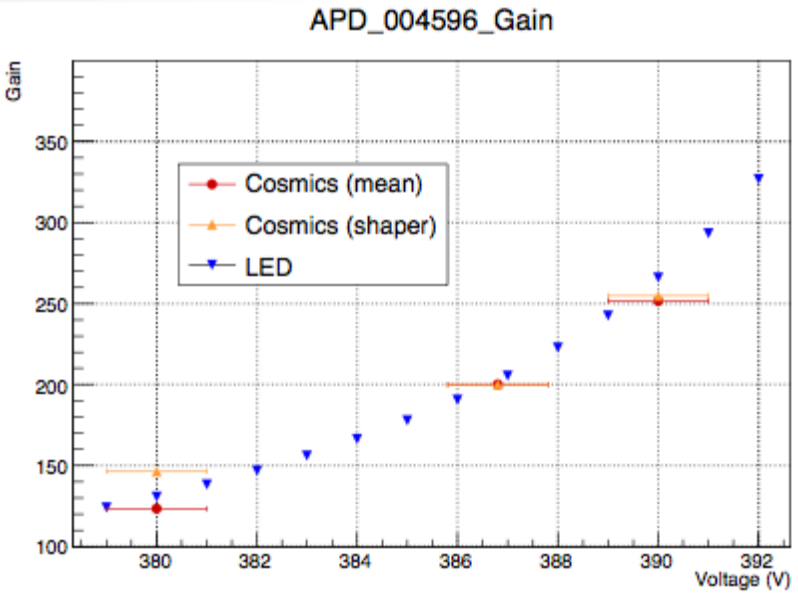
BACKUP SLIDES

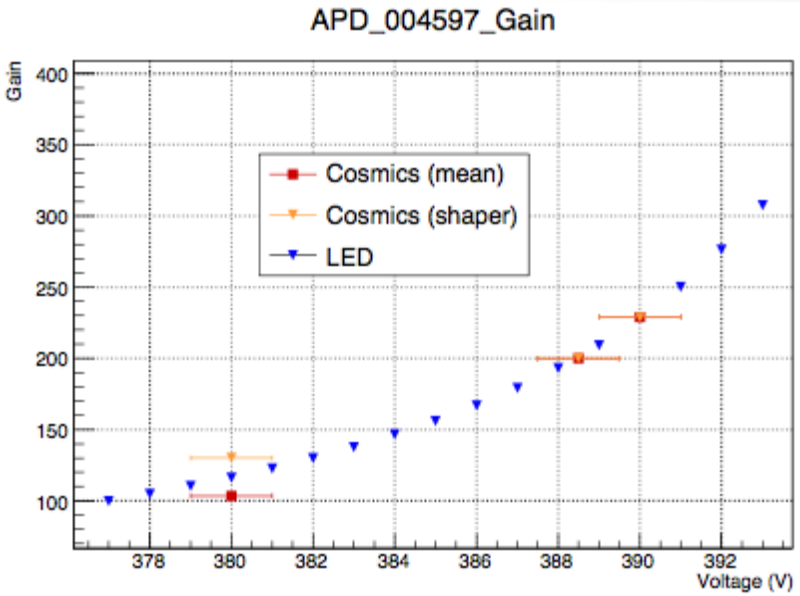
R&D activities in Italy
LAAPD

R&D LAAPD: control of the gain

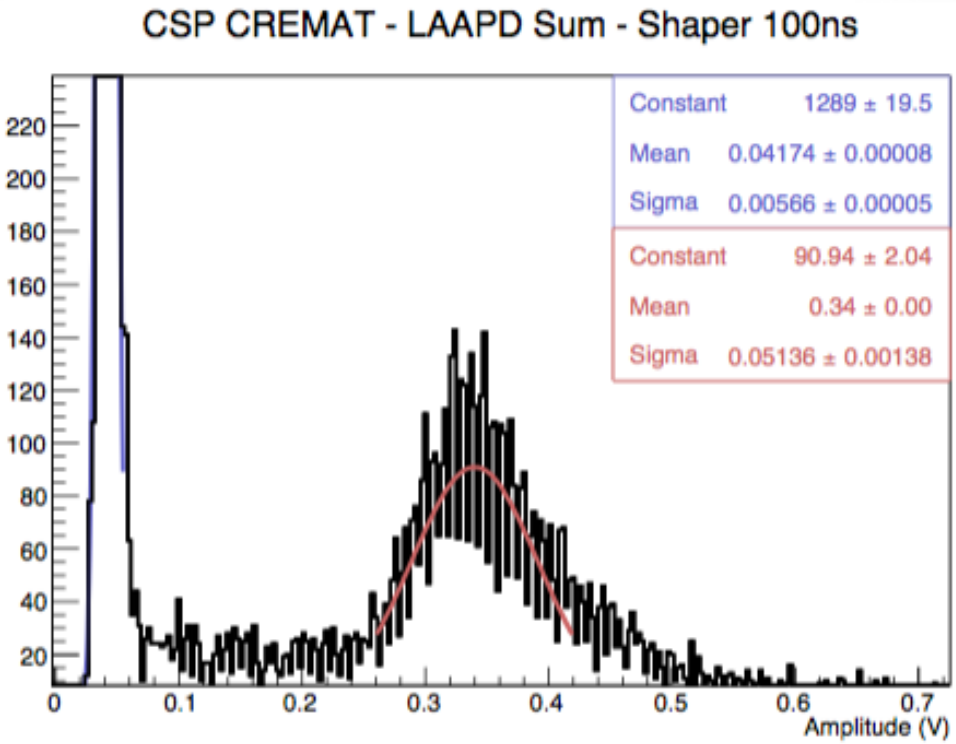
- Hamamatsu data for APDs
  - G=50 HV=364V
  - Vbd=411V
  - Based on this info we measured a G=190 @ 400V
- Gain measurement performed with LED
  - Differences with hamamatsu data!
- Gain values based on new measurement
  - G=200 → HV1=385.8V HV2=388.5V
  - Vbd=400V for both APDs







R&D LAAPD: signal after shaping for the two APD's and for the sum

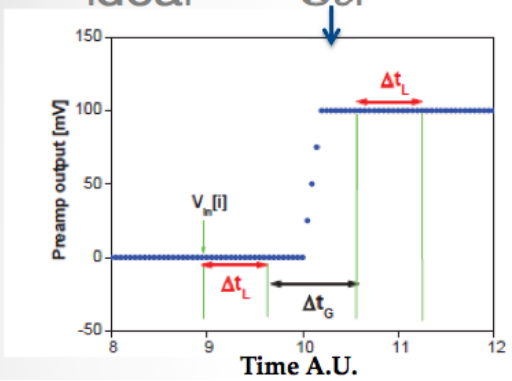


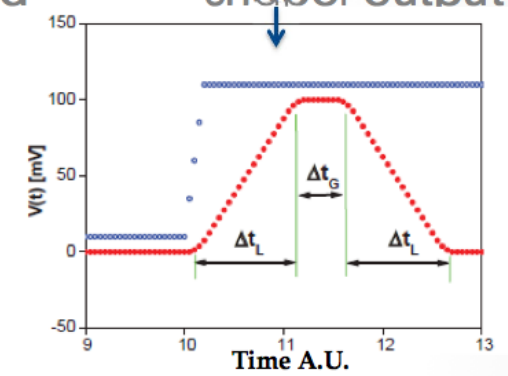
	Signal (mV)	Noise (mV)	S/N	ENE (MeV)
LAAPD1	121.1±0.6	3.71±0.03	32.6±0.3	0.91±0.02
LAAPD2	176.8±0.8	4.21±0.04	42.0±0.5	0.71±0.02
LAAPD Sum	398.3±1.1	5.66±0.05	52.7±0.6	0.55±0.02

R&D LAAPD: shaper software

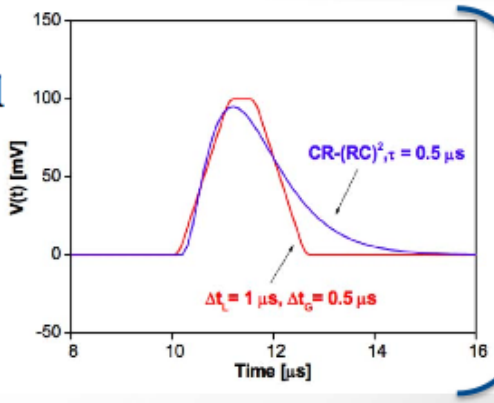
Algorithm details: trapezoidal filter

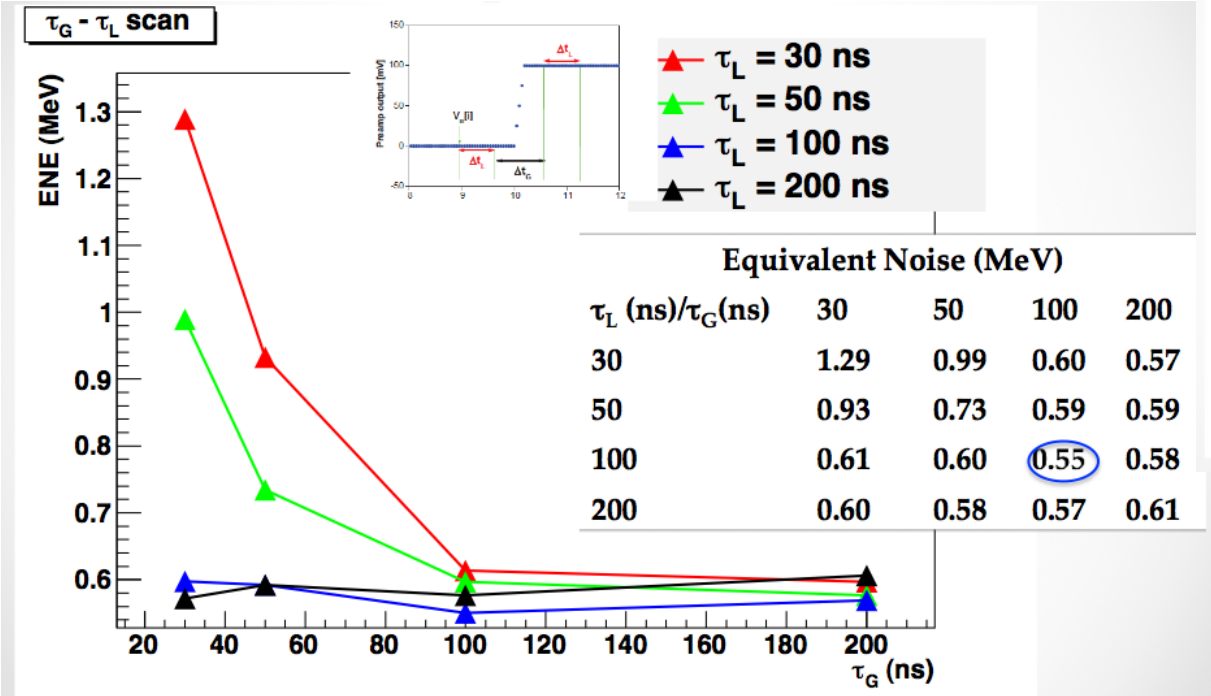
- Ideal CSP and Shaper output





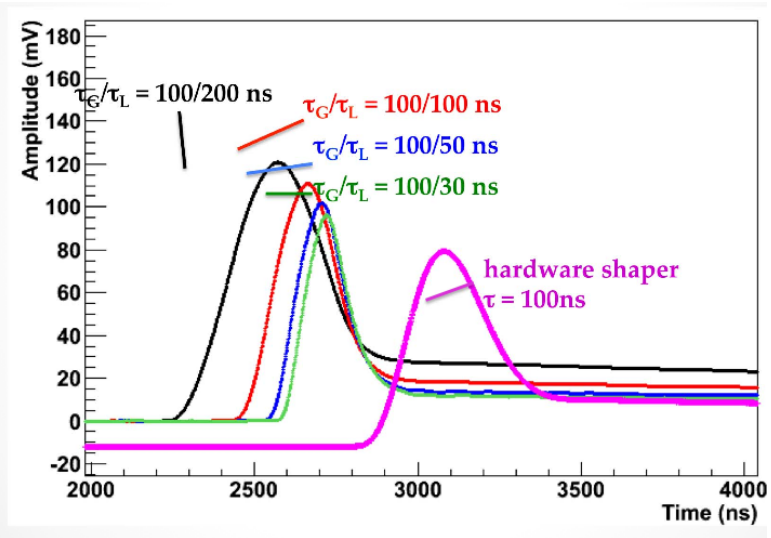
trapezoidal filter vs CR-RC²





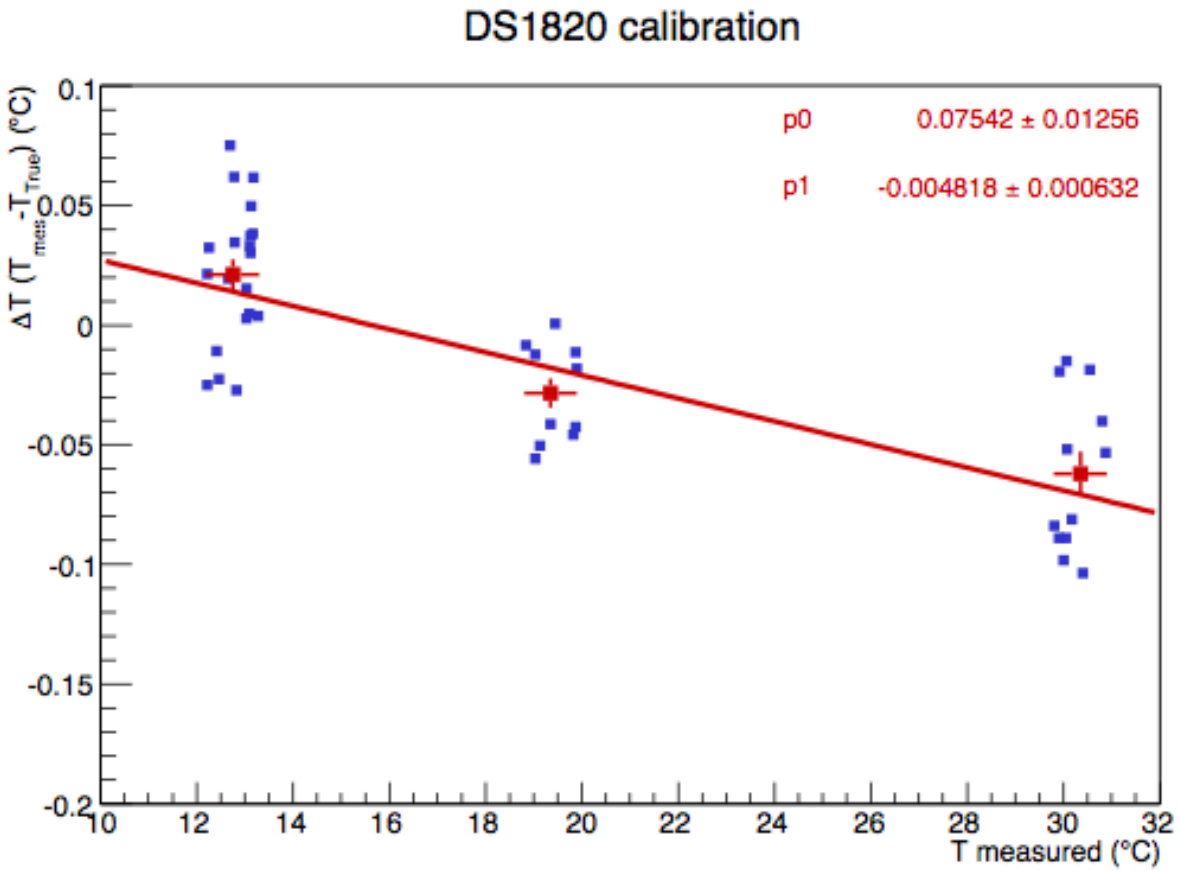
Equivalent Noise (MeV)

τ_L (ns)/τ_G(ns)	30	50	100	200
30	1.29	0.99	0.60	0.57
50	0.93	0.73	0.59	0.59
100	0.61	0.60	0.55	0.58
200	0.60	0.58	0.57	0.61



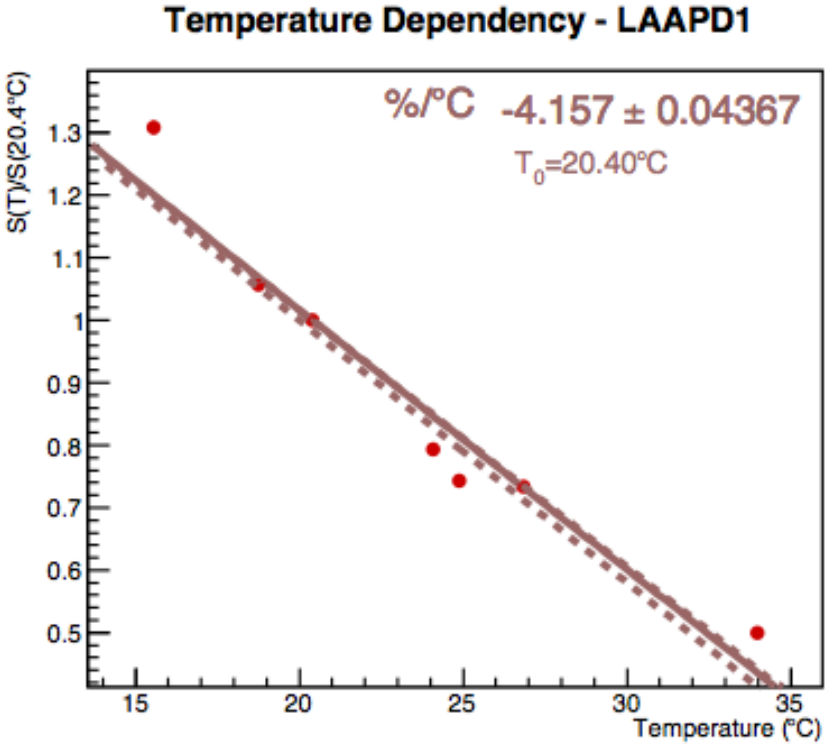
R&D activities in Italy
LAAPD temperature stability studies

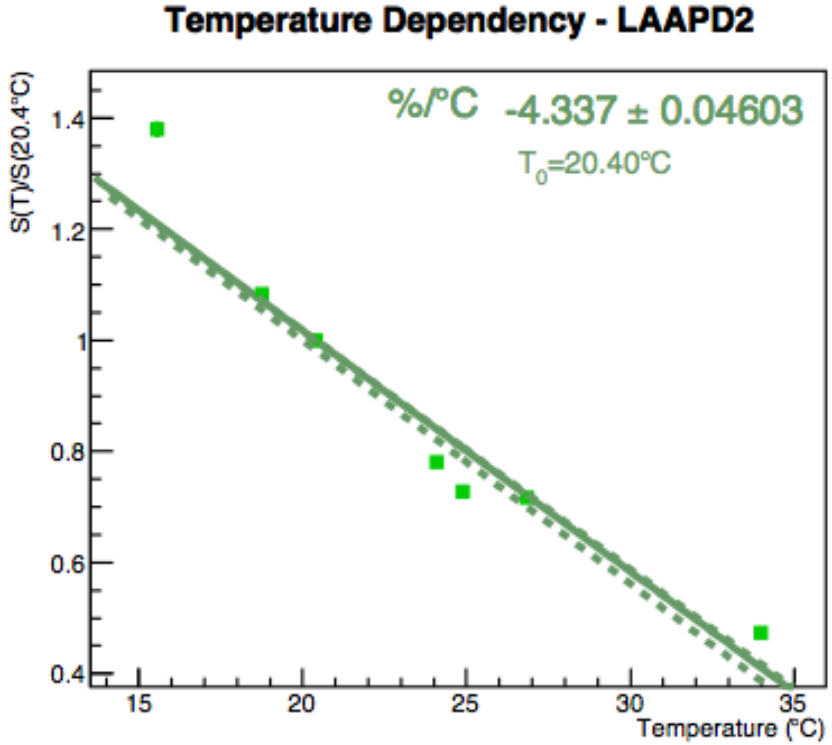
R&D LAAPD: calibrazione del sensore di temperatura



- ΔT : difference between measured T by DS18S20 and the certified sensors HD2701
- DS1820 is enough precise for our purpose
- Mean ΔT is below 0.05°C

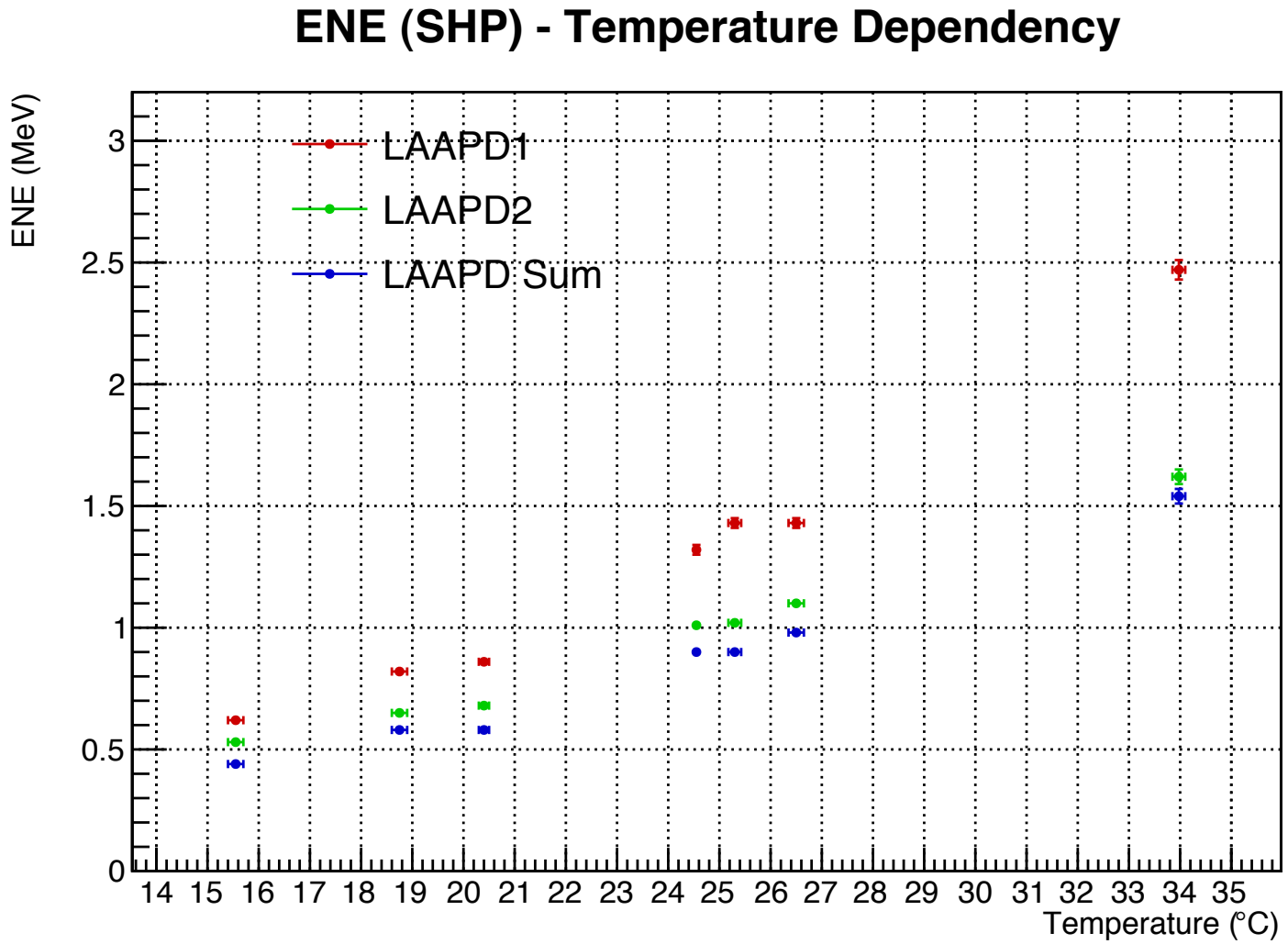
R&D LAAPD: dipendenza del guadagno dalla temperatura





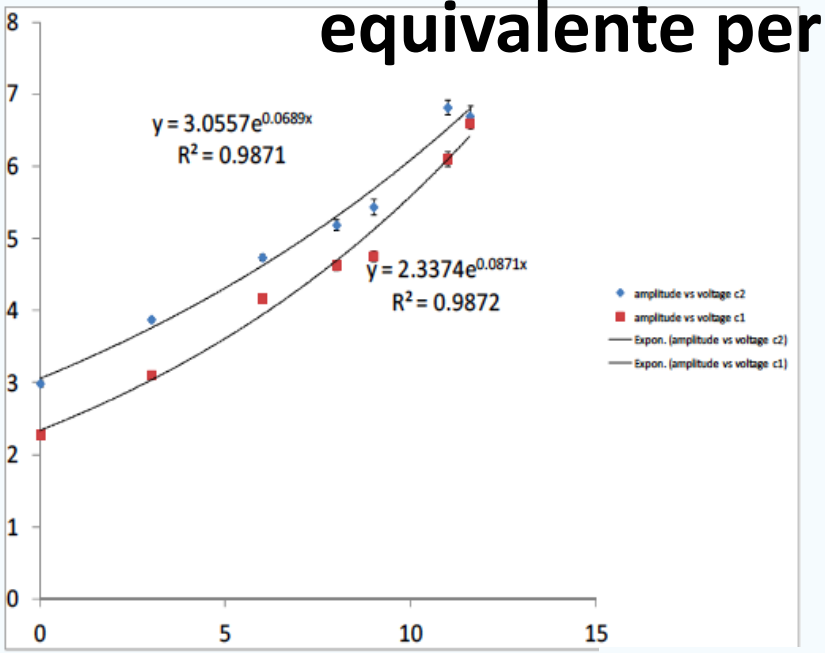
- Mean energy deposit measured at each T are normalized to the deposit @ T_0=20.4°C
- A fit is performed to extract the temperature dependency
- The CsI light yield temperature dependency has to be subtracted in order to obtain the APD dependency
  - From PDG : CsI(pure) dLY/dT=-1.4%/°C with T0 at room temperature (not better specified)

R&D LAAPD: noise equivalente in funzione della temperatura



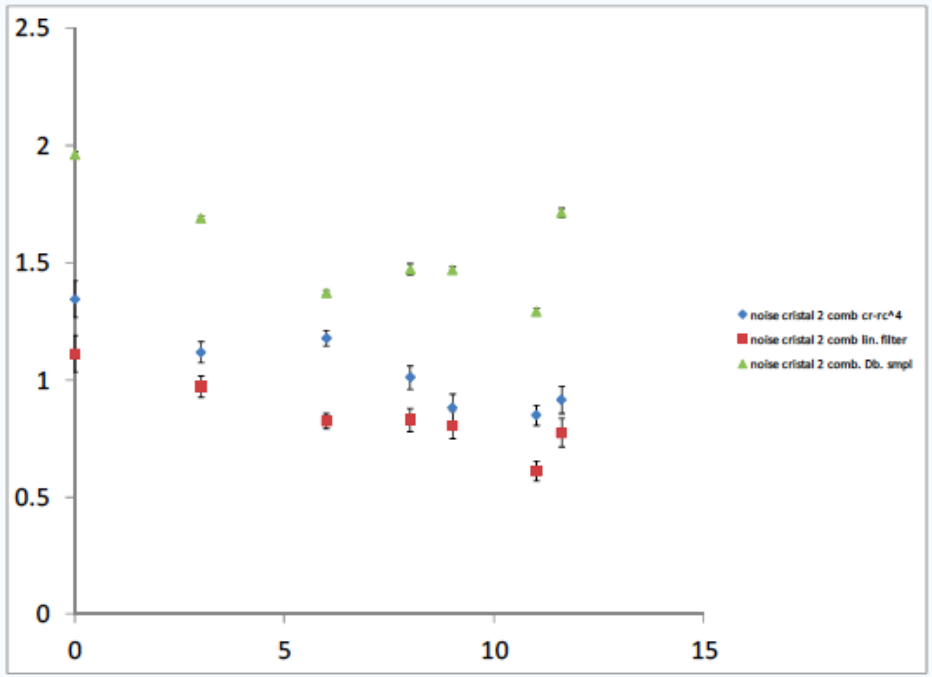
R&D activities in Italy
APD excelitas

R&D excelitas: ampiezza degli APD e noise equivalente per due APD's per cristallo



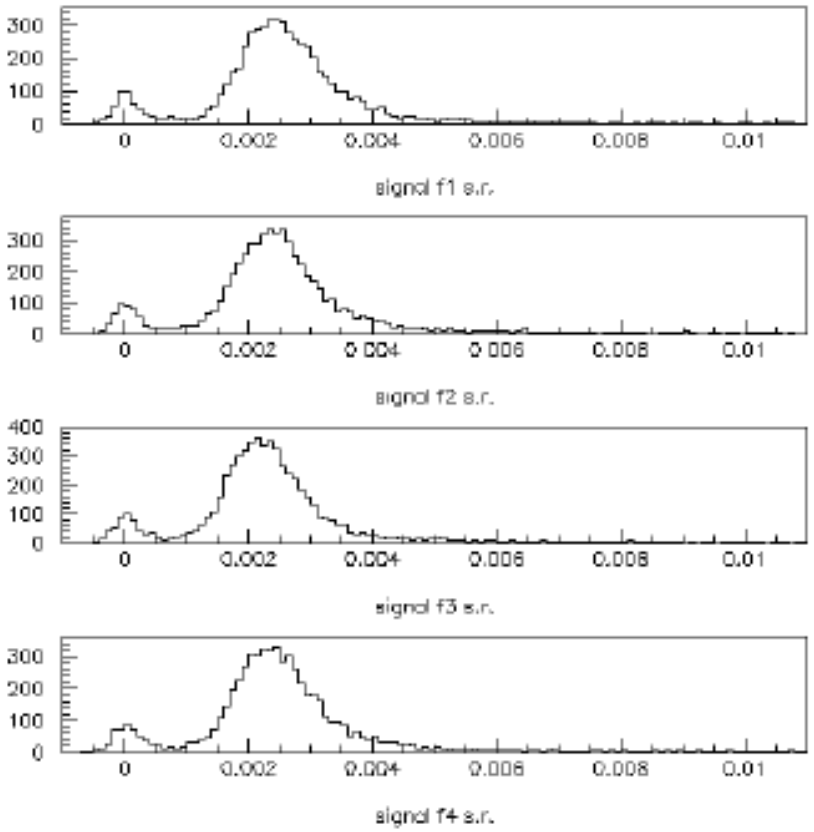
Ampiezze dei due APD's in funzione della differenza di tensione rispetto a quella nominale.

Il range dinamico di utilizzo degli APD e' superiore, in tutti quelli che abbiamo avuto, a 15 V,



Il rumore in MeV , con tre algoritmi differenti:
in verde : double sampl.
in blu : CR-RC⁴.
in rosso : shap. Lineare.
Nuovo cristallo.
Costante di tempo 75 nsec.

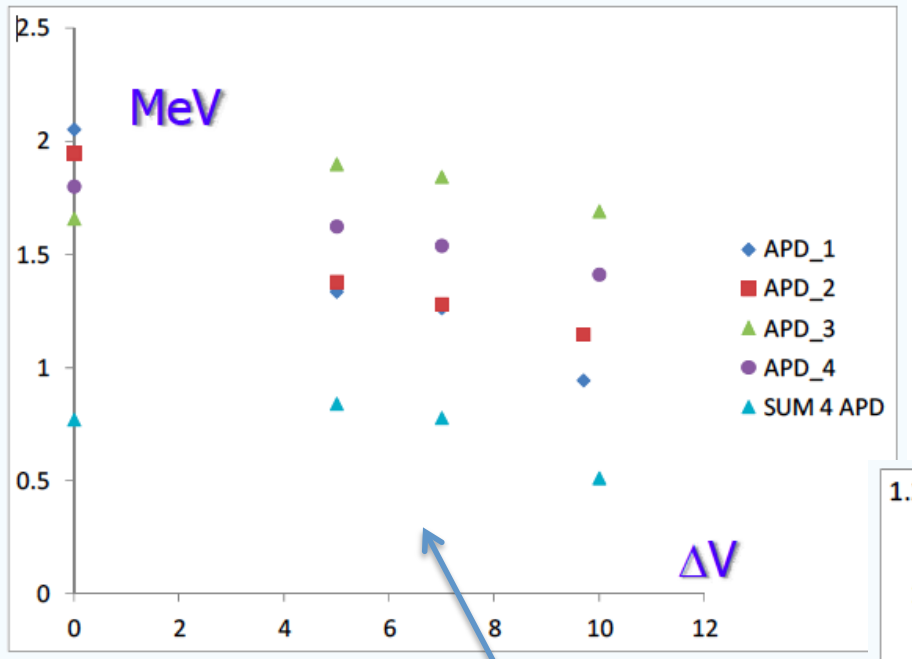
R&D excelitas: test con 4 APD's per cristallo

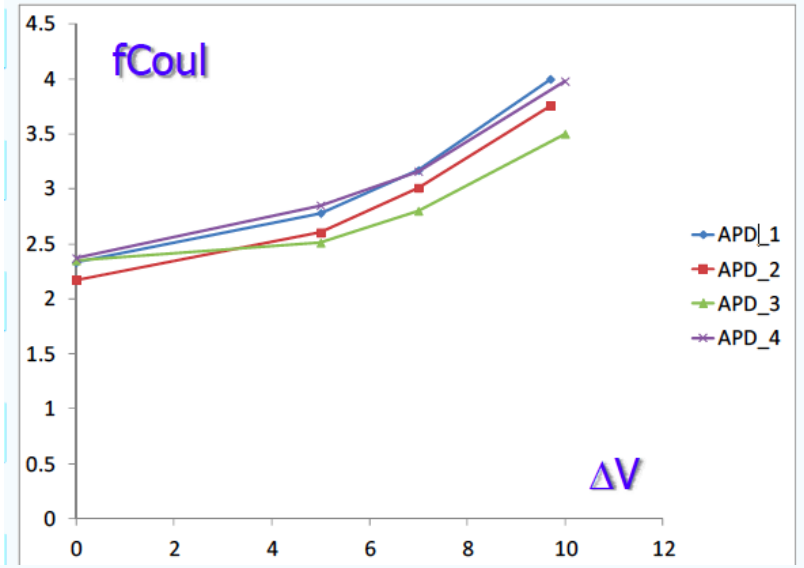


Spettri di ampiezza dei quattro APD ciascuno alimentato a tensione nominale (G=200)

Le differenze di ampiezza sono al di sotto del 10%

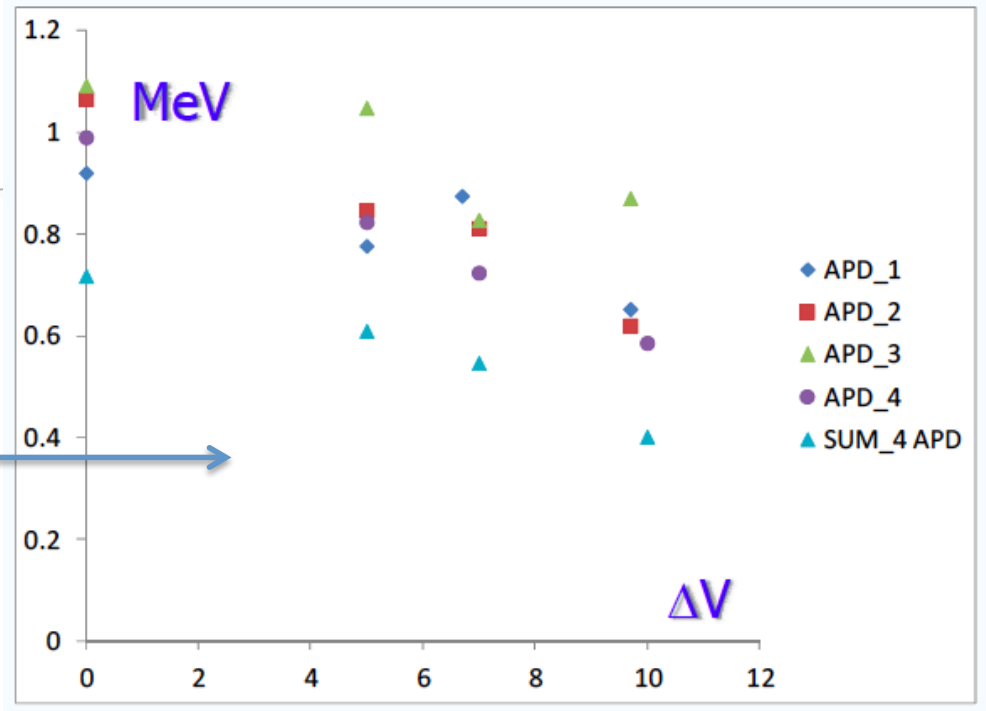
R&D excelitas: ampiezza APD e noise equivalente per double sampling e dopo lo shaping lineare





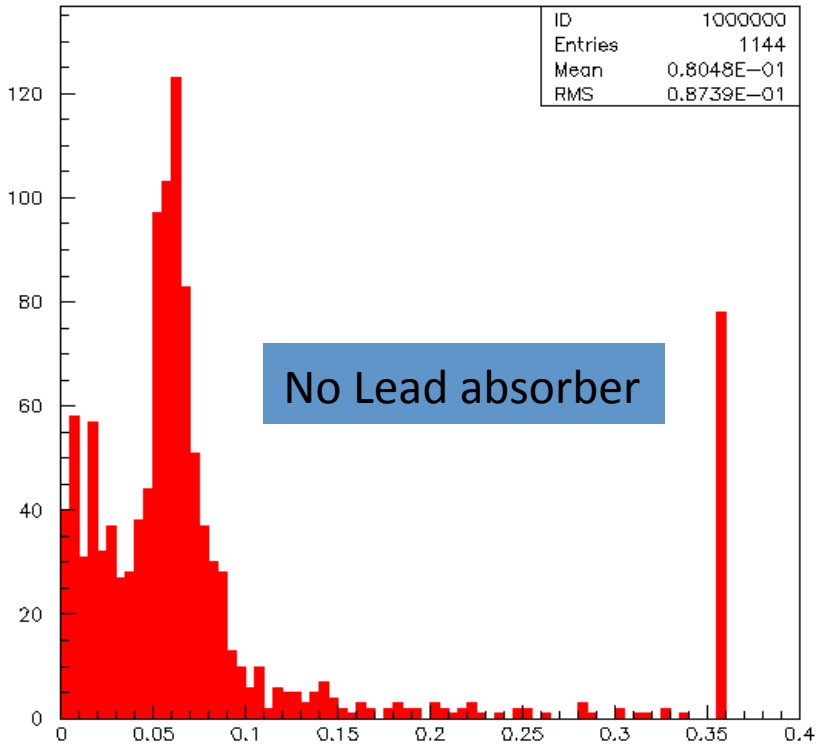
Double sampling CSP level

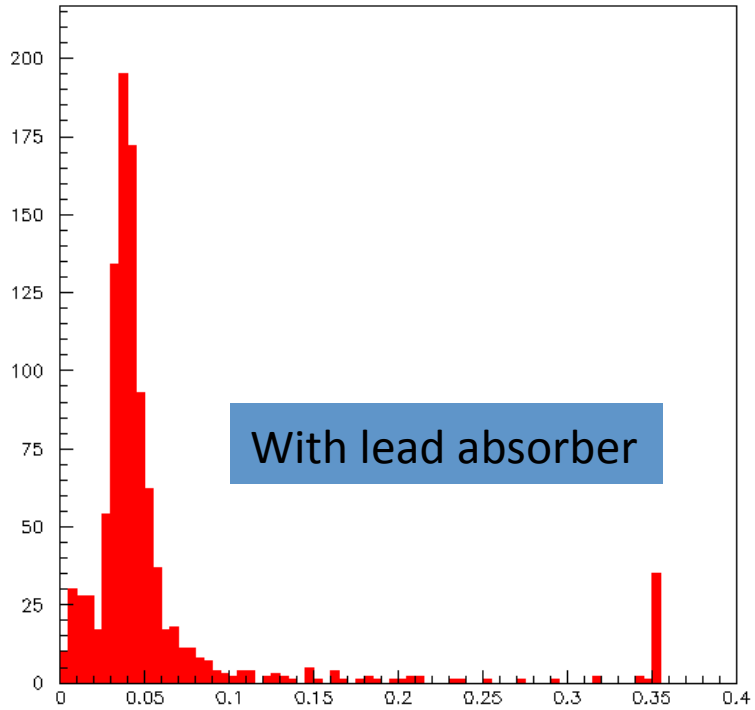
Linear shaping



R&D activities in Italy
1” photopentodes 2/cristallo

R&D PP 2”: comparison with and wo absorber

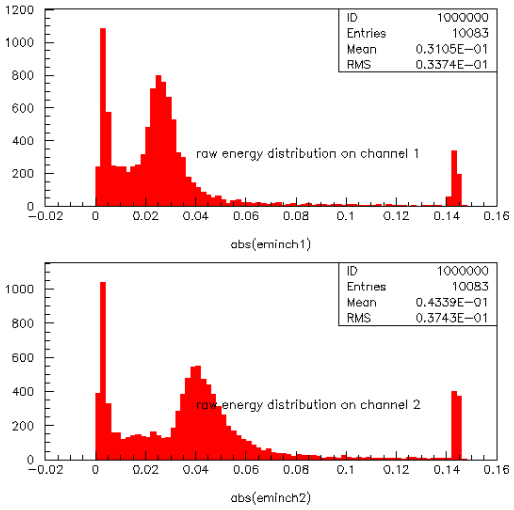


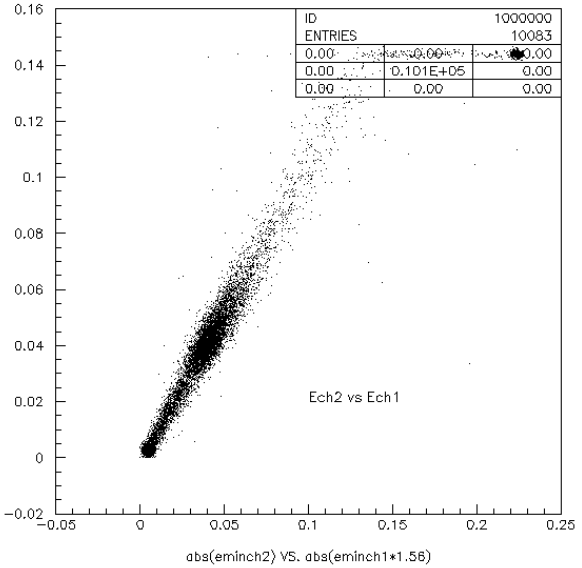


R&D PP 1”: raw energy, channel equalization, S/N ratio

Perugia INFN Istituto Nazionale di Fisica Nucleare

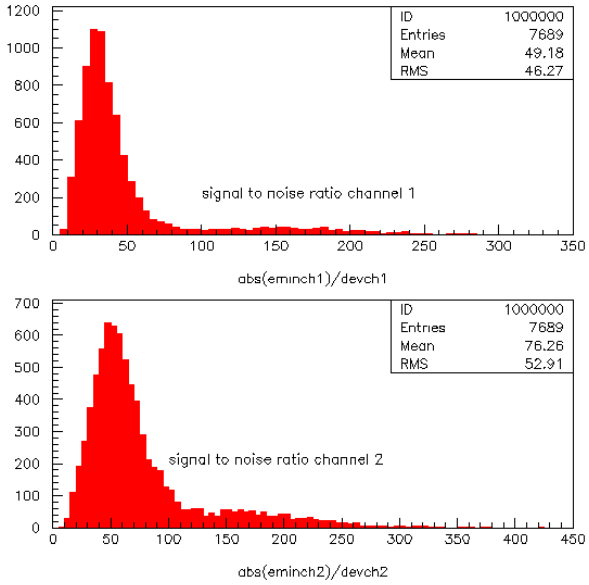
Raw energy





Correlation of the two channels after correction

S/N

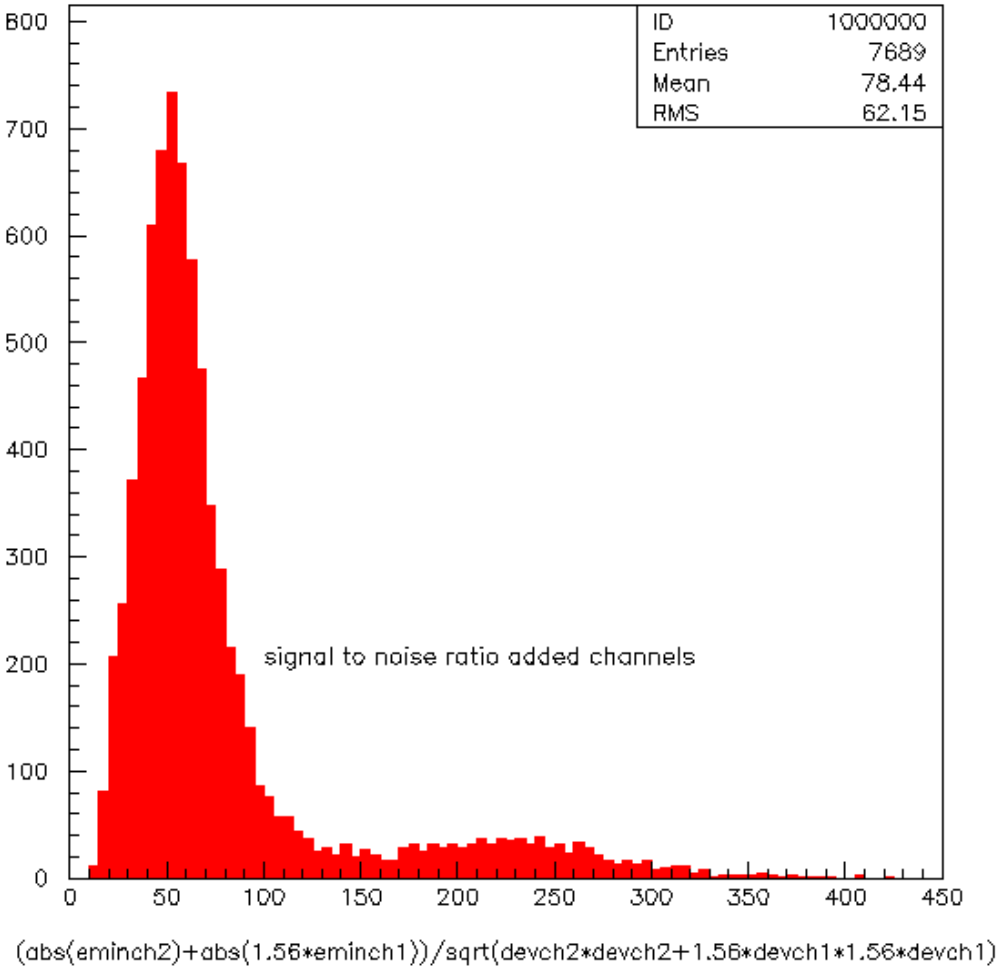


Signal/noise on ch1 = 49.
Assuming a that muon delivers
30 MeV noise level is about 650 KeV

Signal to noise ratio on ch2 = 76
under the same assumption
We estiate a noise level of about 400 KeV

No shaping has ever been applied to
This analysis

R&D PP 1”: S/N ratio channels combination



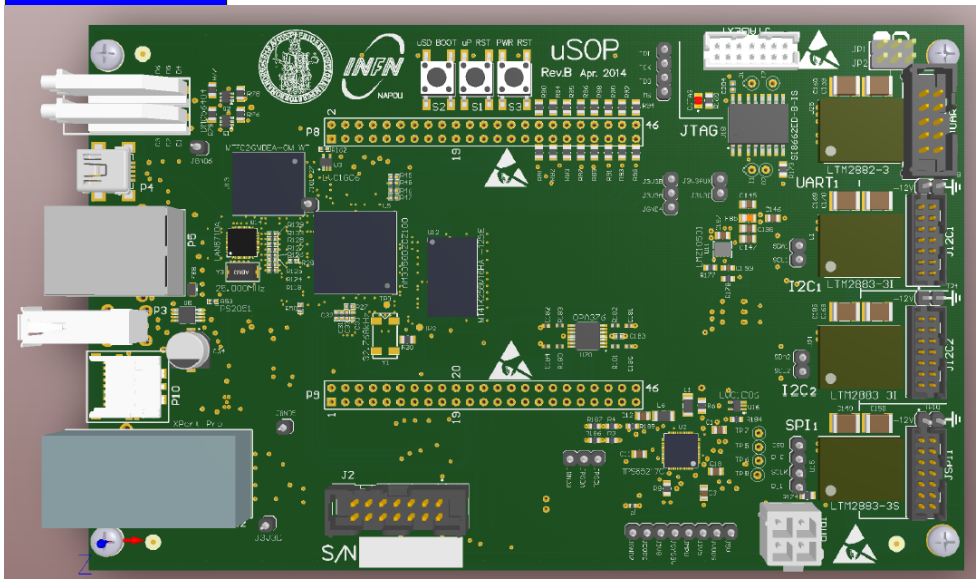
Signal to noise ratio is 78.

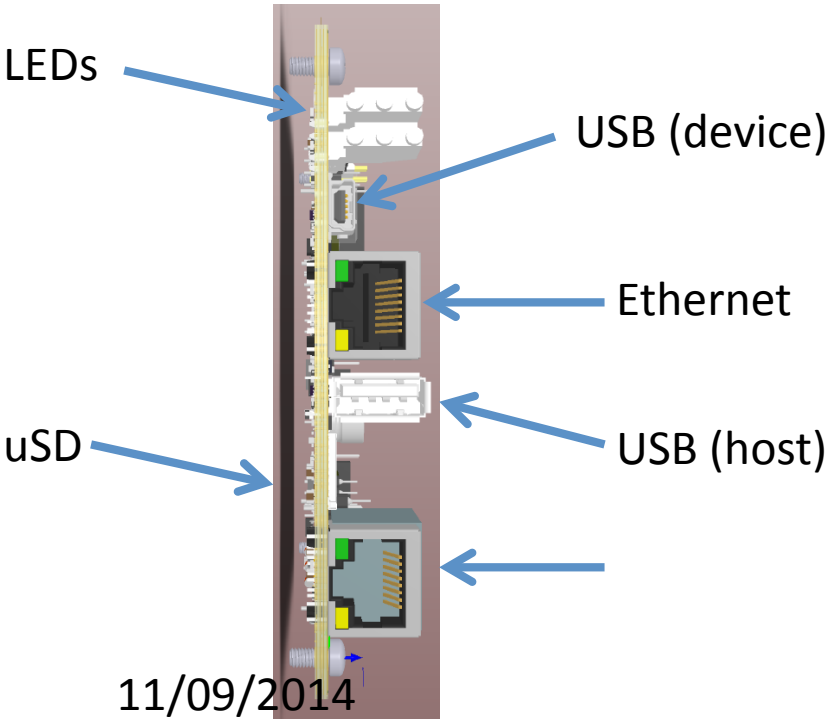
We do not gain much from channels combination.

It is maybe due to the huge difference between the 2 photopentodes

R&D activities in Italy
uSOP (Service Oriented Platform for slow control)

uSOP: REV B





- Cortex A8 uP @ 1GHz
- Linux OS (Debian)
- 2 GB Flash
- 512 MB RAM
- Designed as a possible general platform for Belle2 slow-controls
- Designed for easy manteinability
- 3U Eurocard form factor
- Derived-from and compatible-with BeagleBoneBlack

uSOP: Project Status of the HW

- Design of first version (Rev. B) completed
- 5 PCBs produced and received
- Waiting for components:
  - Two ICs in back-order: 16 weeks delivery time from RS, Digi-Key, Mouser, …
  - Looking for alternative suppliers (brokers, …)
- Assembly completed possibly by end of June (conditioned by component availability)
- Then tests, debug, troubleshooting, …

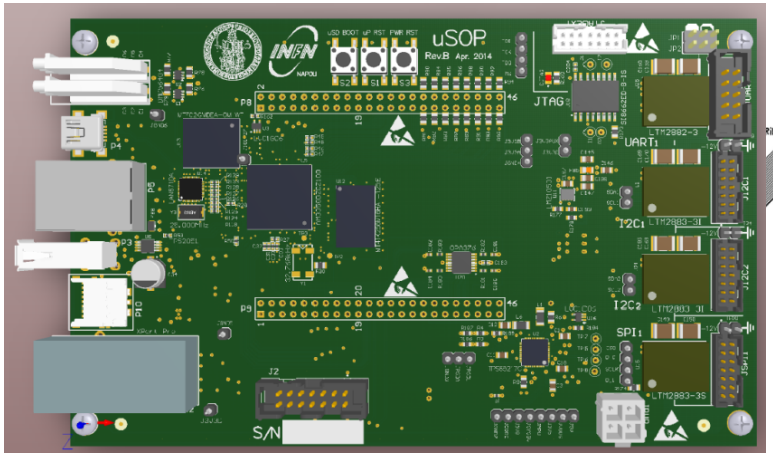
uSOP: Project Status of the SW

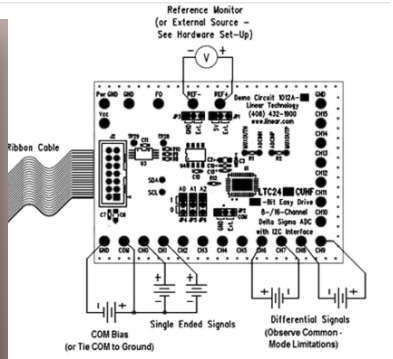
- Linux porting is available *open-source* (Debian)
- Software for JTAG programming of Xilinx FPGA completed and tested successfully
- Software for ADC read-out via I2C in progress
- Software for IPMI(*)-like features in progress

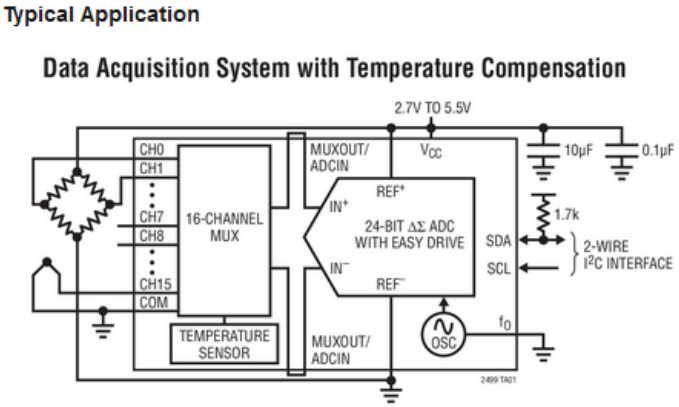
- Hot spots:
  - Integration in EPICS
  - Definition of high-level software architecture :
    - push vs. pull
    - publish/subscribe
    - synch. vs. asynch
    - Network usage and role
    - web or stand-alone GUI

*Intelligent Platform Management Interface

uSOP: Temperature monitoring







- In this revision, uSOP does not include peripherals. Instead, it supports protocols for remote data acquisition via field busses (I2C, SPI, JTAG, …)
- For temperature monitoring in Belle2, LTC2499 seems to be a perfect candidate:
  - 24-bit, ΣΔ architecture
  - 50/60 Hz line noise filter
  - 7.5 Hz sampling Rate
  - Direct Sensor Digitizer
  - Direct Temperature Measurement
  - I2C interface
- uSOP can be directly interfaced with the DC1012A-A board available from Linear Tecnology for performance evaluation