Tests of LYSO crystals for use in the electromagnetic calorimeters

A.M.Artikov, V.Y.Baranov, Yu.A.Budagov, Yu.I.Davydov, V.V.Glagolev, A.V.Simonenko, A.N.Shalyugin, V.V.Tereschenko, Z.U.Usubov

JINR, Dubna

K.Afanasiev, M.A.Batouritsky, I.Emel'yanchik, V.Shevtsov

NC PHEP BSU, Minsk

ESMART-2012

Dubna

Crystal calorimeters in the past and future

Crystal Ball, SPEAR, SLAC	**NaI(Tl)**
SND, VEPP-2M, VEPP-2000 Novosibirsk	**NaI(Tl)**
L3, LEP, CERN	**BGO**
KTeV, FNAL	**CsI**
CLEO c, CESR, Cornell	**CsI(Tl)**
BABAR PEP II SLAC	**CsI(Tl)**
BELLE KEK B KEK	**CsI(Tl)**
CMS, LHC, CERN	**PWO**
PANDA, FAIR	**PWO-II**
Mu2e, FNAL	**LYSO**

Properties of Crystal Scintillators

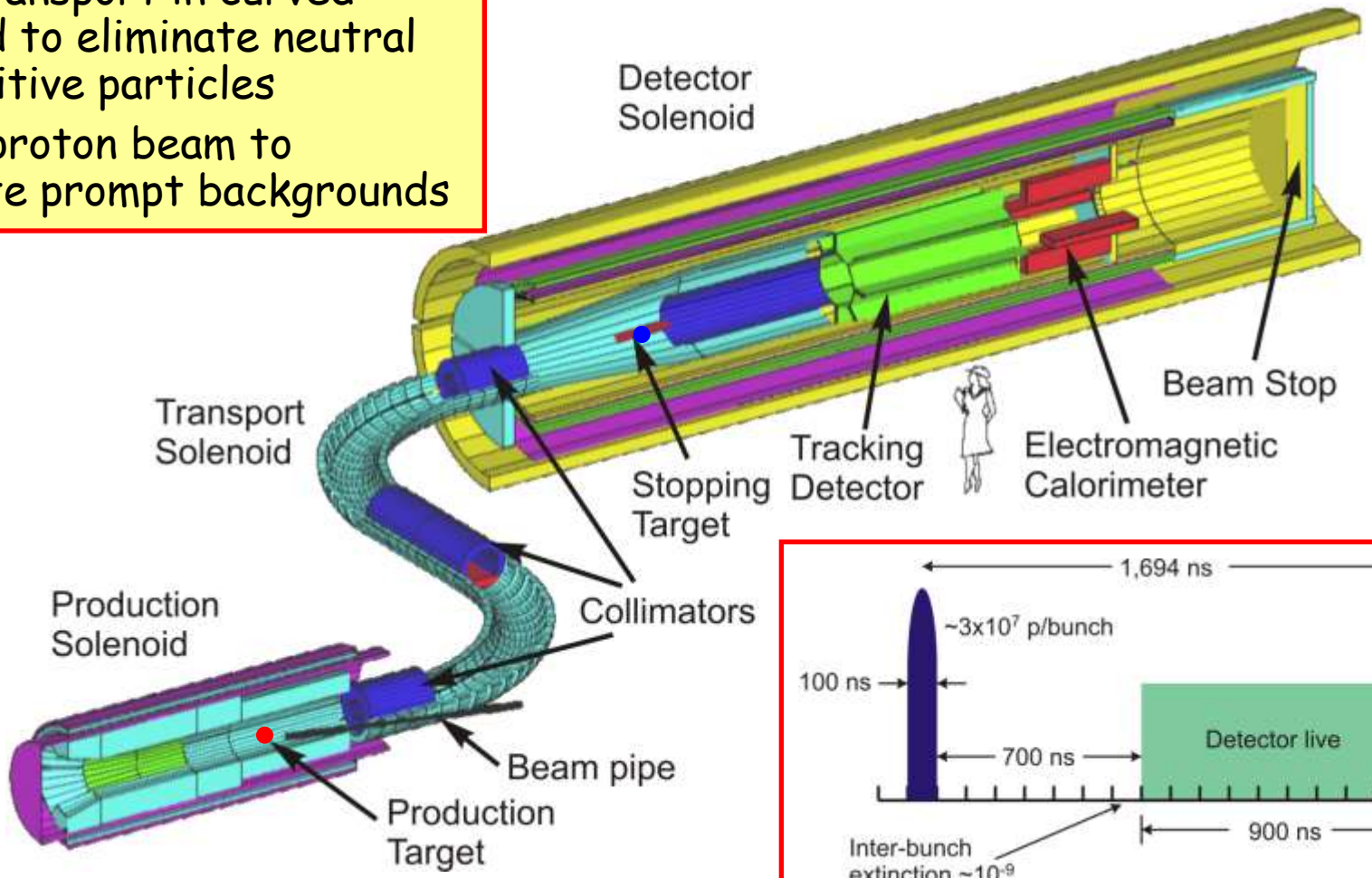
Crystal	NaI(Tl)	CsI(Tl)	BaF_2	BGO	$PbWO_4$	LSO(Ce)	LYSO	GSO(Ce)
Density (g/cm^3)	3.67	4.51	4.89	7.13	8.3	7.40	7.1	6.71
Melting Point (ºC)	651	621	1280	1050	1123	2050	2050	1950
Radiation Length (cm)	2.59	1.85	2.06	1.12	0.9	1.14	1.2	1.37
Molière Radius (cm)	4.8	3.5	3.4	2.3	2.0	2.3		2.37
Interaction Length (cm)	41.4	37.0	29.9	21.8	18	21		22
Refractive Index [a]	1.85	1.79	1.50	2.15	2.2	1.82	1.81	1.85
Hygroscopicity	Yes	Slight	No	No	No	No	No	No
Luminescence [b] (nm) (at peak)	410	560	300 220	480	560 420	420	420	440
Decay Time [b] (ns)	230	1300	630 0.9	300	50 10	40	40-45	60
Light Yield [b,c] (%)	100	45	21 2.7	9	0.1 0.6	75	75	30
d(LY)/dT [b] (%/ ºC)	~0	0.3	-2 ~0	-1.6	-1.9	?		?
Volume Price ($/cm^3$)	1 to 2	2	2.5	7	2.5	-		-

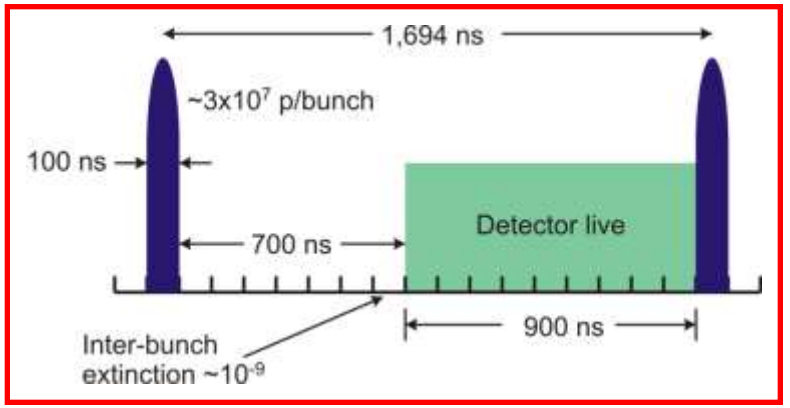
Mu2e Spectrometer

Salient Features

- Graded solenoidal field to maximize pion capture (MELC)
- Muon transport in curved solenoid to eliminate neutral and positive particles
- Pulsed proton beam to eliminate prompt backgrounds

for every incident proton
0.0025 μ^-'s are stopped in the
17 0.2 mm Al target foils





Stopped Muon Backgrounds to $\mu^-N \rightarrow e^-N$

Stopped Muon Backgrounds

Muon decay in orbit (DIO):

$\mu^- N_{A,Z} \rightarrow e^- \nu_\mu \nu_e N_{A,Z}$

Note: $E_e < mc^2 - E_{NR} - E_b$ not $E_e < \frac{1}{2}mc^2$

- defeated by good energy resolution

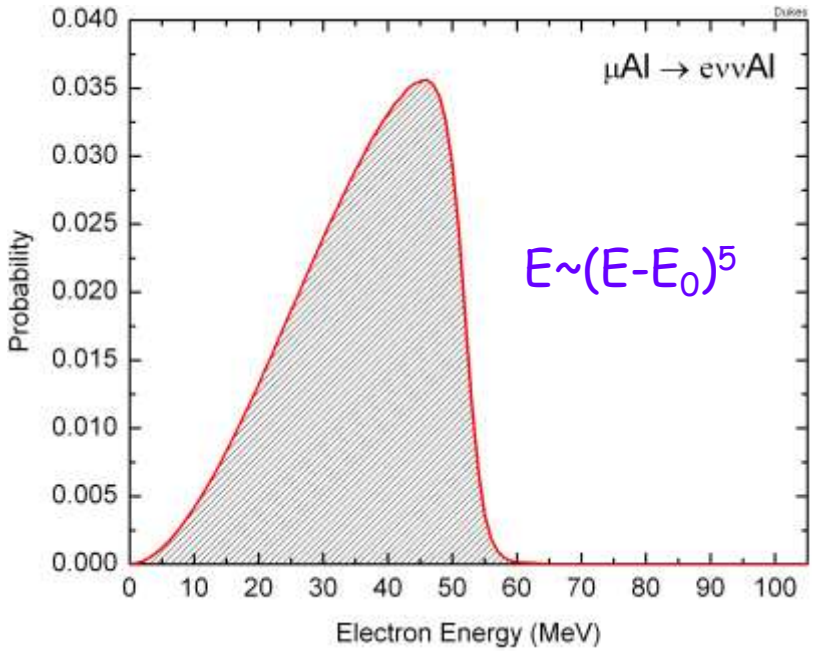
Radiative muon capture (RMC):

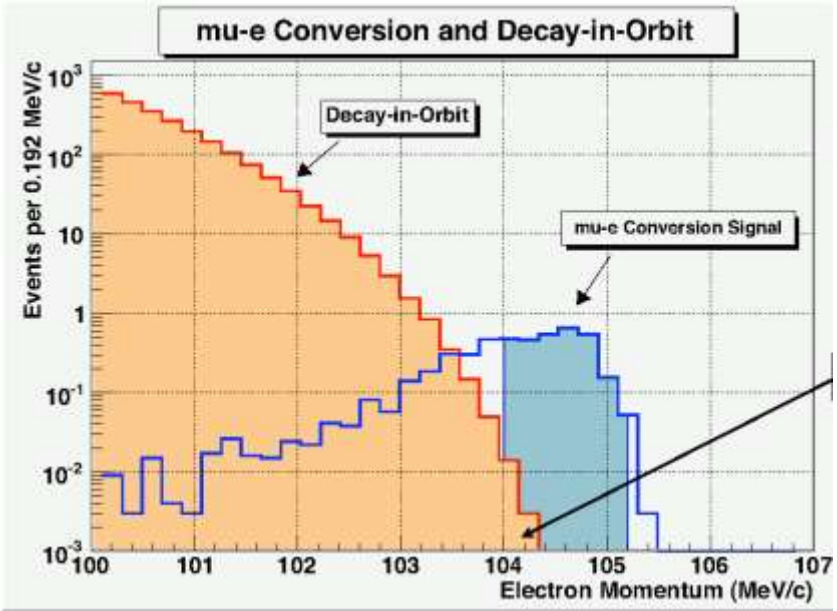
$\mu^- N_{A,Z} \rightarrow \nu_\mu \gamma N_{A,Z-1}$, $\gamma \rightarrow e^+ e$

Note: $E_{\gamma max}(Al) = 102.5$ MeV

- restricts choice of stopping targets
- defeated by good energy resolution

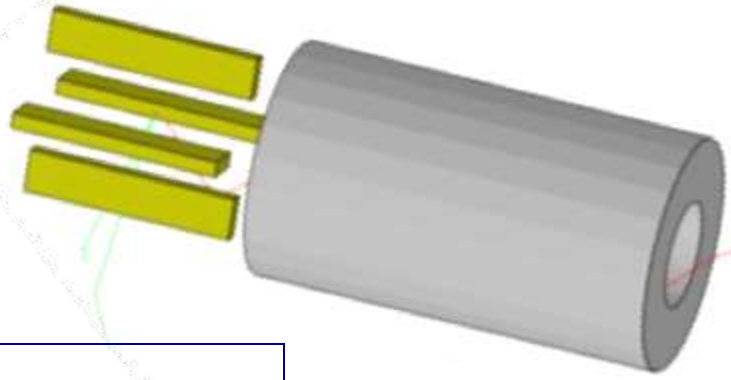
$m_{Z-1} > m_Z$





Mu2e Detector

B_z=1.0 T uniform field in Tracker + ECal



B_z=1.2 T

B_z=2.0 T

μ beam

ECAL:
Trigger + confirmation of a real track.

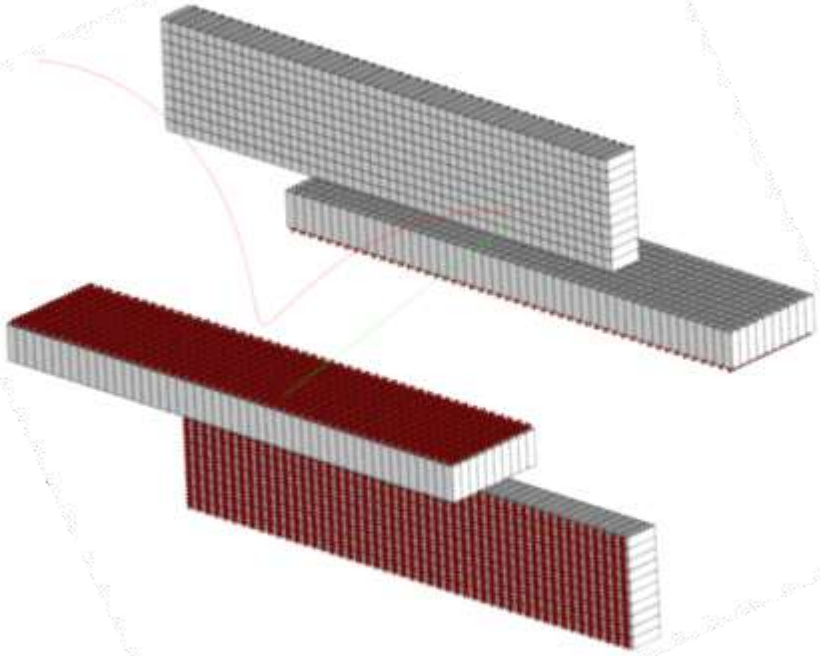
Tracker:
Precision momentum measurement:

Stopping target:
In graded field

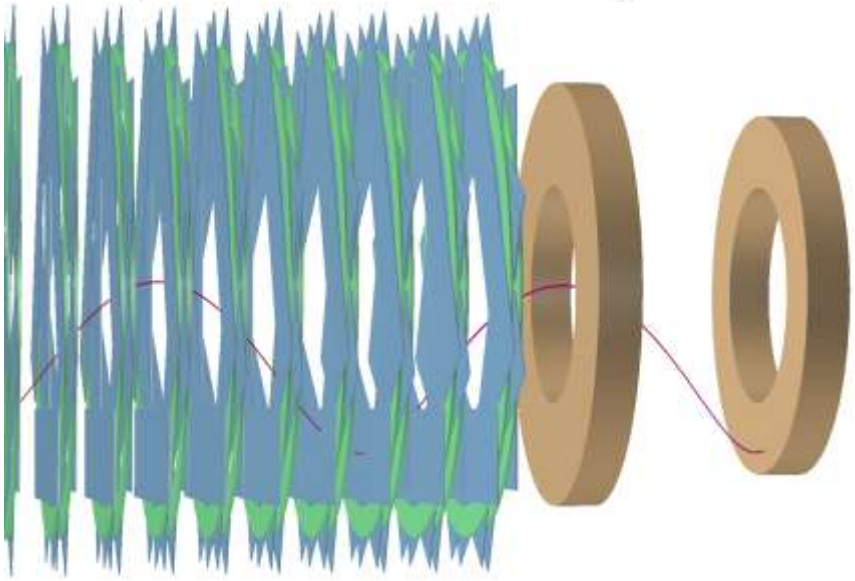
Require:
σ(p) ≈ 150 keV at p=105 MeV

Useful tracks make 2 to 3 turns inside the tracker.

Electromagnetic Calorimeter

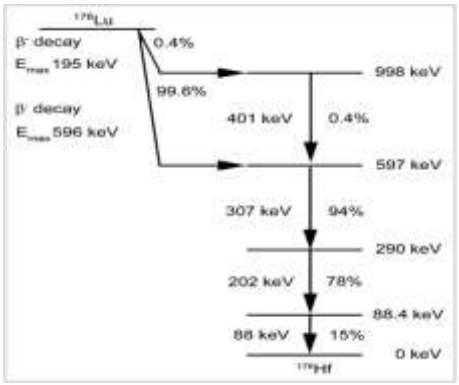


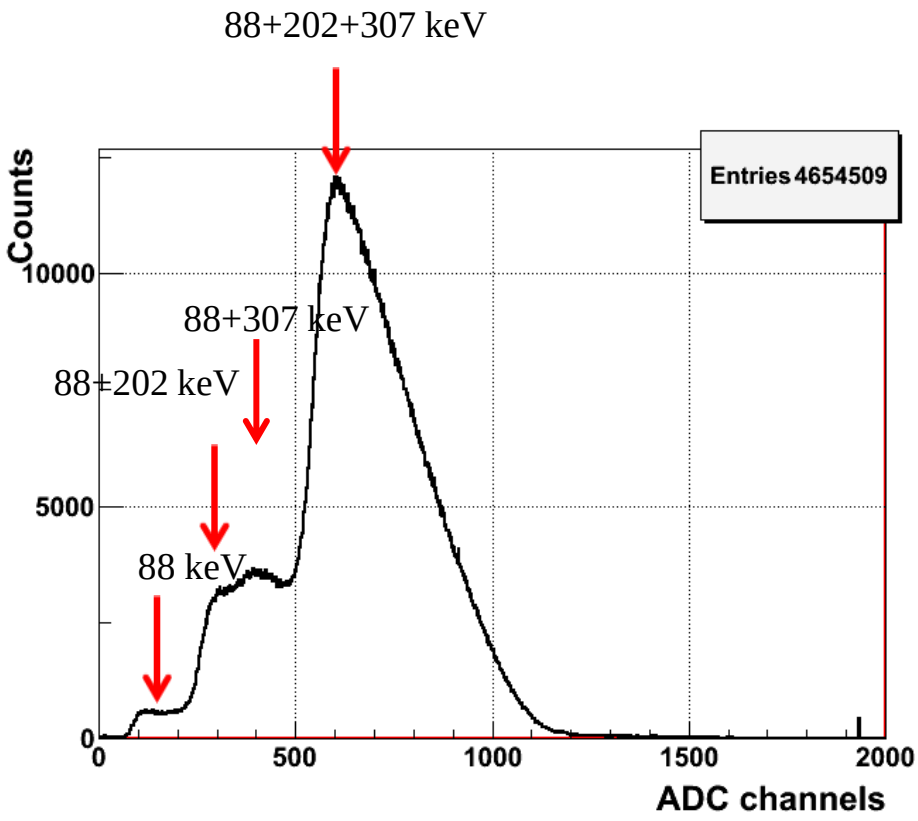
- 12 X 44 LYSO crystals of $3 \times 3 \times 11$ cm^3 for each vane
- $\sigma(E) \approx 5$ MeV at 105 MeV.
- Main job is to trigger on interesting tracks.
- Spatial match of extrapolated track will help reject badly mis-reconstructed tracks.
- Most tracks from DIO curl inside.

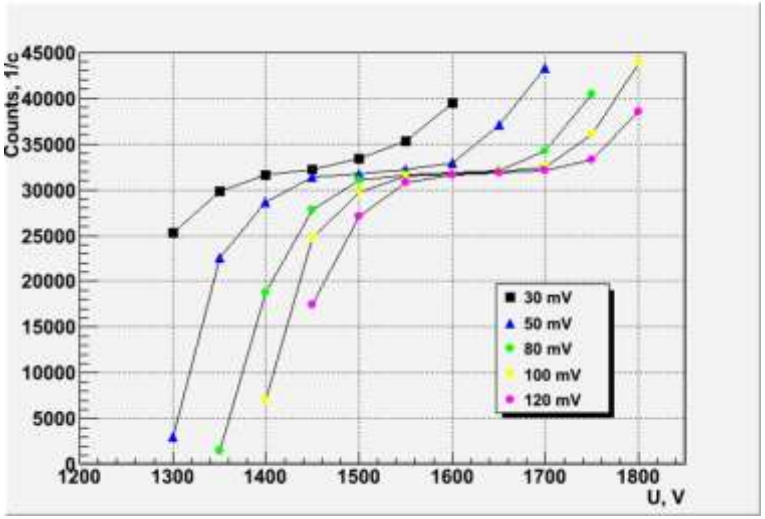


Two discs are separated by ~1/2 "wavelength"

LYSO intrinsic radioactivity







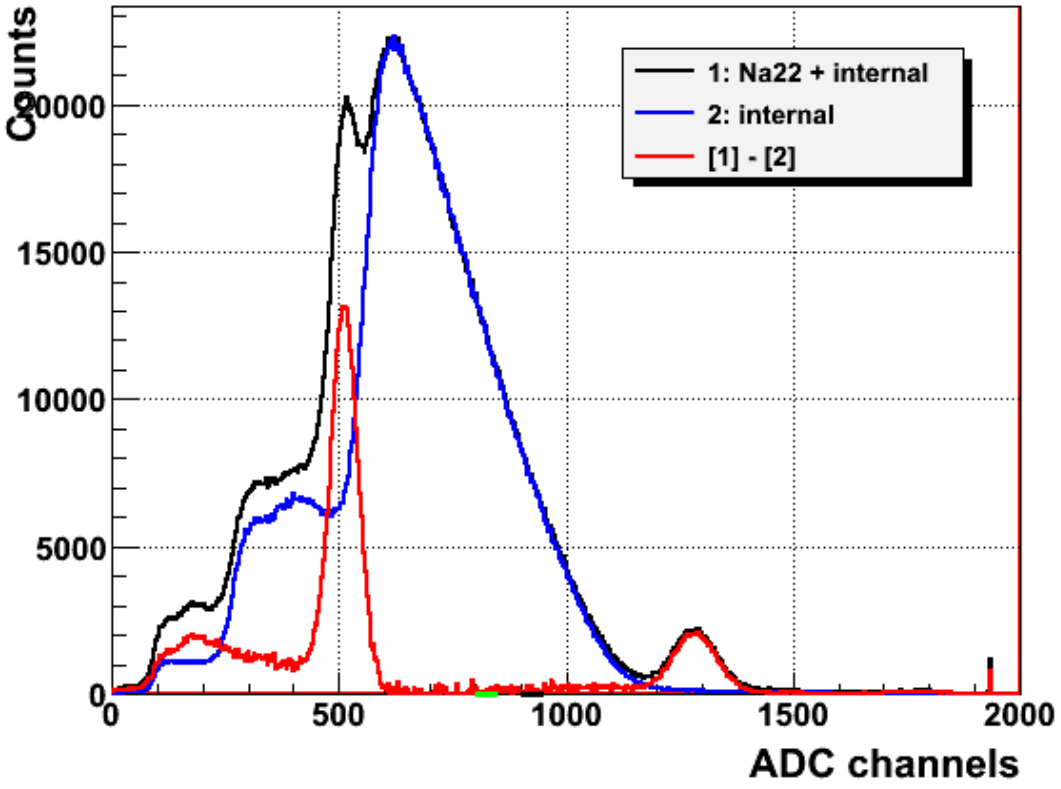
Average rate is

~ **31930±179 c^{-1}**

OR

38.4±0.2 c^{-1} g^{-1}

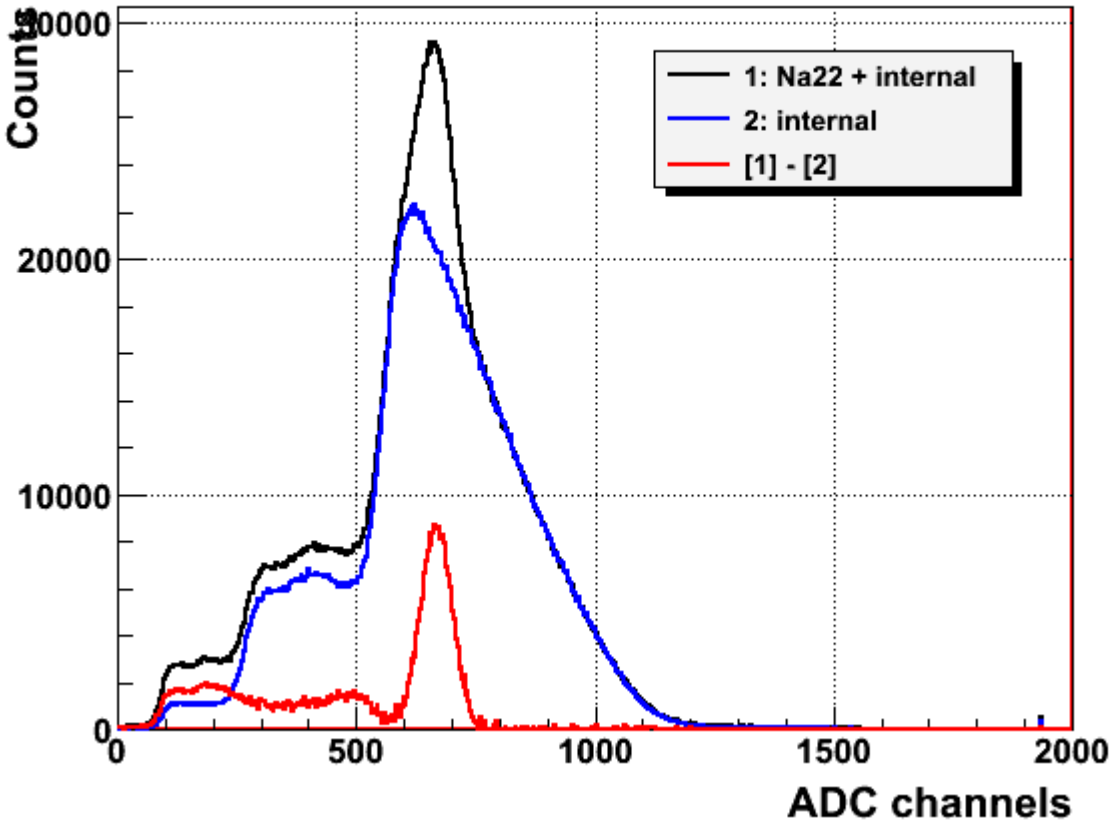
^{22}Na spectrum: self triggering



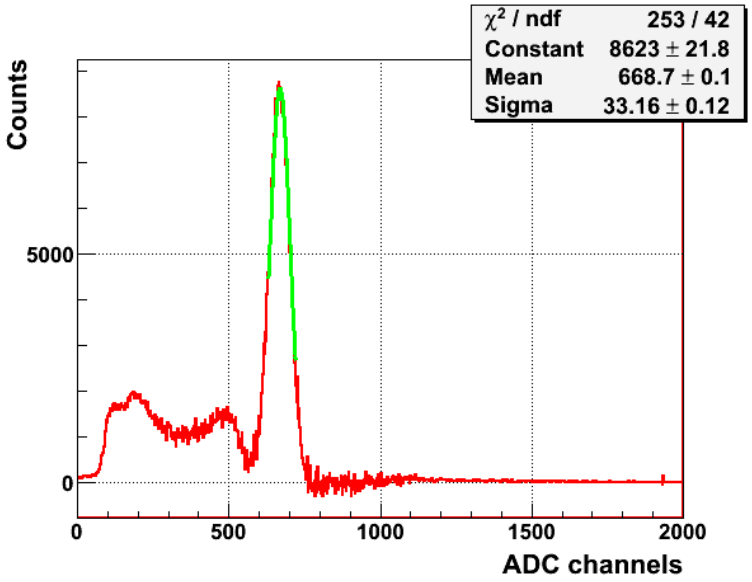
511 keV: σ/E = 5.75%

1275 keV: σ/E = 3.7%

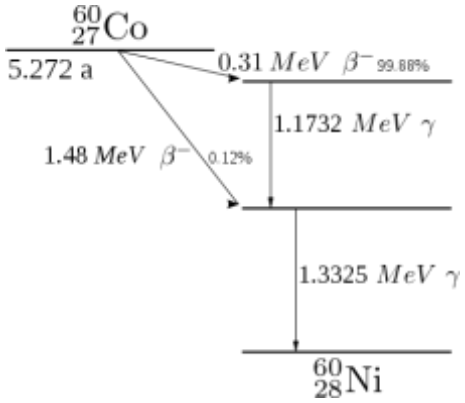
^{137}Cs spectrum



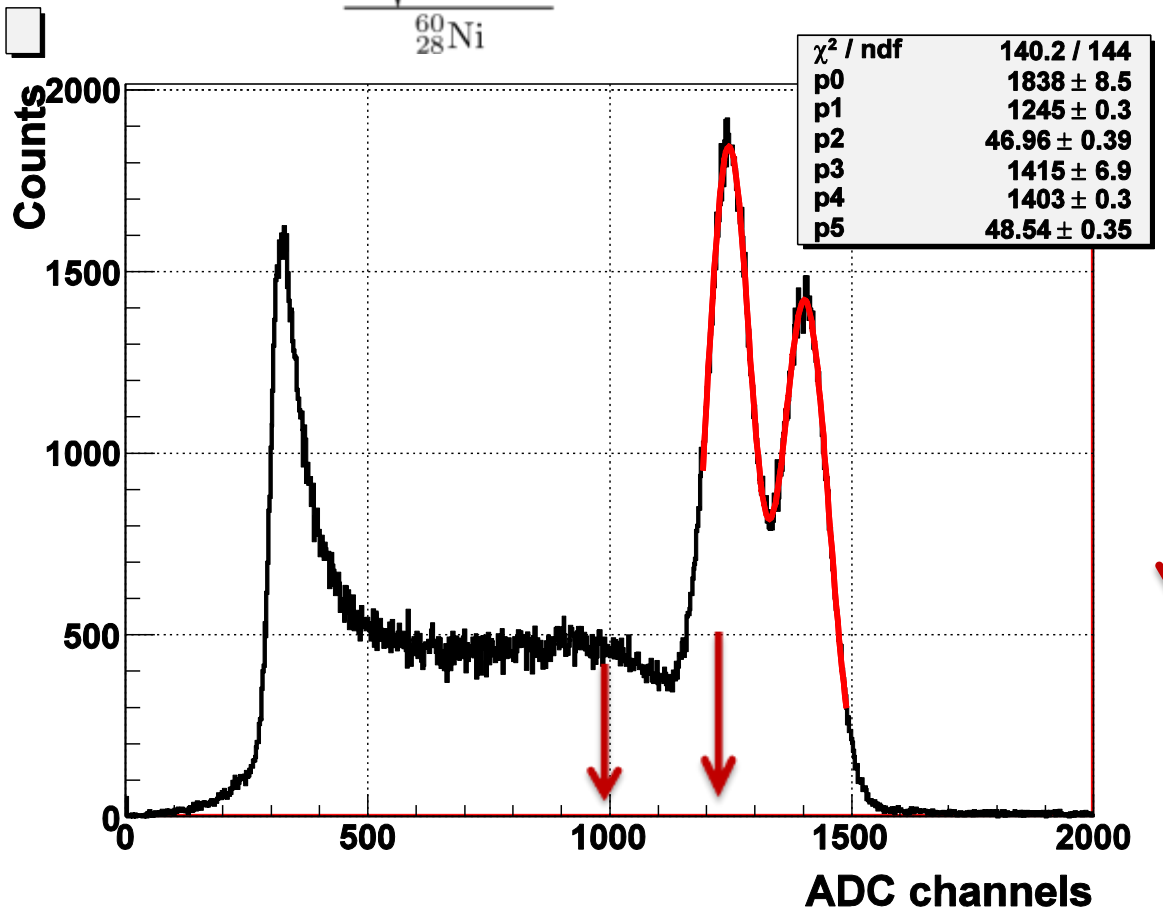
662 keV: σ/E = 4.8%



LYSO irradiation with ^{60}Co γ-source



- Trigger: coincidence with sc. Counter
- Pedestal (97 chan.) is not subtracted



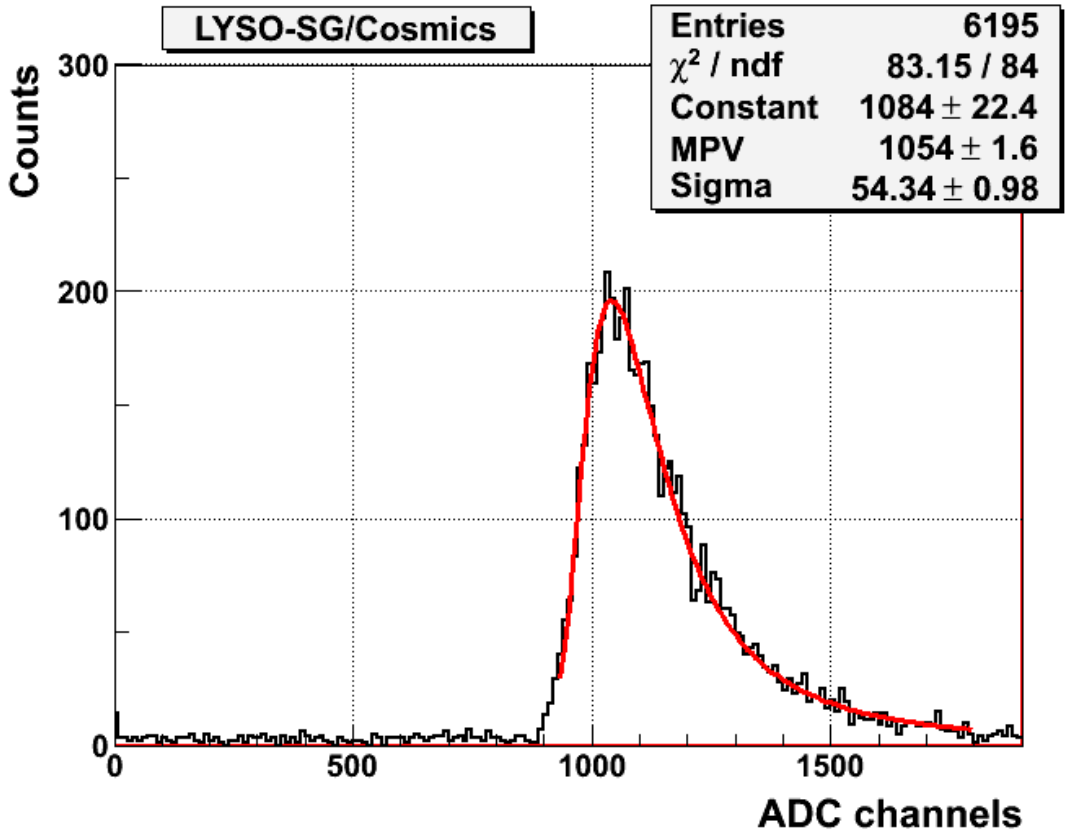
1173 keV: σ/E = 3.9-4.0%

1333 keV: σ/E = 3.6-3.7%

- edges of Compton distributions (ADC channels 994 and 1201)

Subtracting of Compton tails should improve the resolution

Spectrum from cosmic muons



Simulation: MPV = 27.84±1.5 MeV

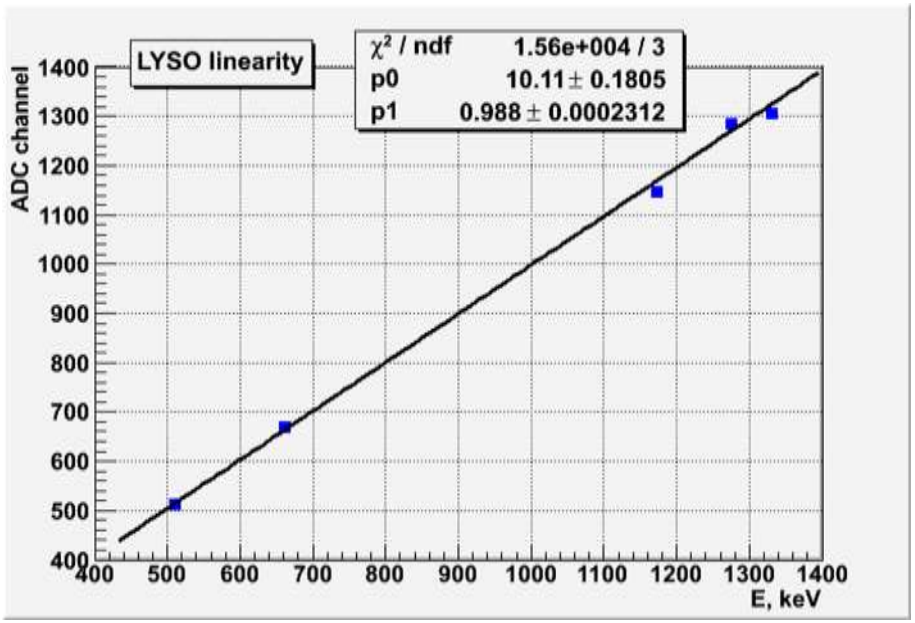
Data: MPV = 263.5±0.4 pC

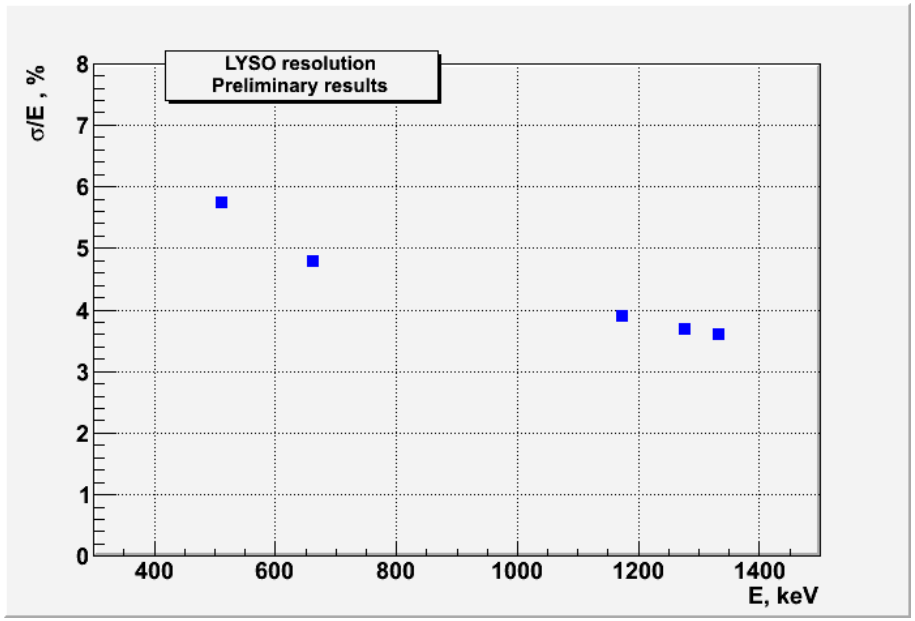
G = $9 \cdot 10^4$ Att = 14 dB

$$N_{ph.e.} = \frac{Q \cdot Att}{q0 \cdot G} \approx 91490 \text{ ph.e.}$$

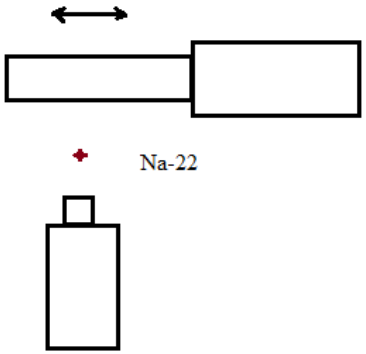
$N_{ph.e.} \approx 3285$ ph.e./MeV

Linearity of the energy response and resolution

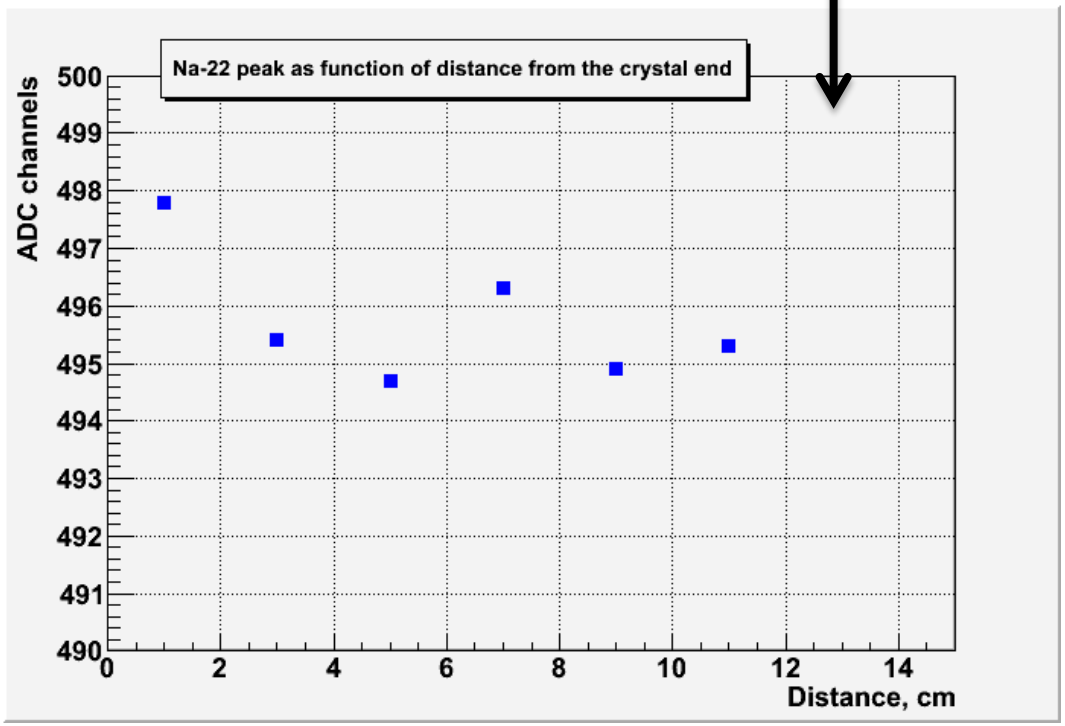




LYSO longitudinal light response uniformity

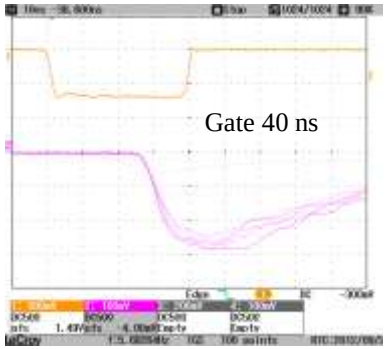


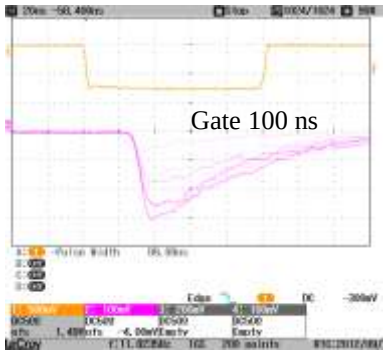
PMT is here

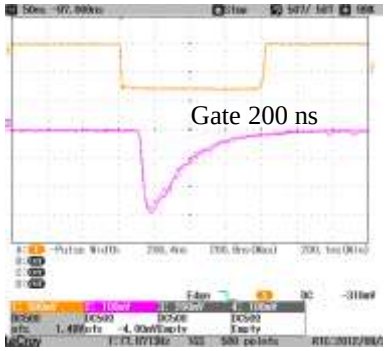


- Short runs to measure LRU
- Distances between source and detectors are 8 cm
- Hard to make any conclusions…

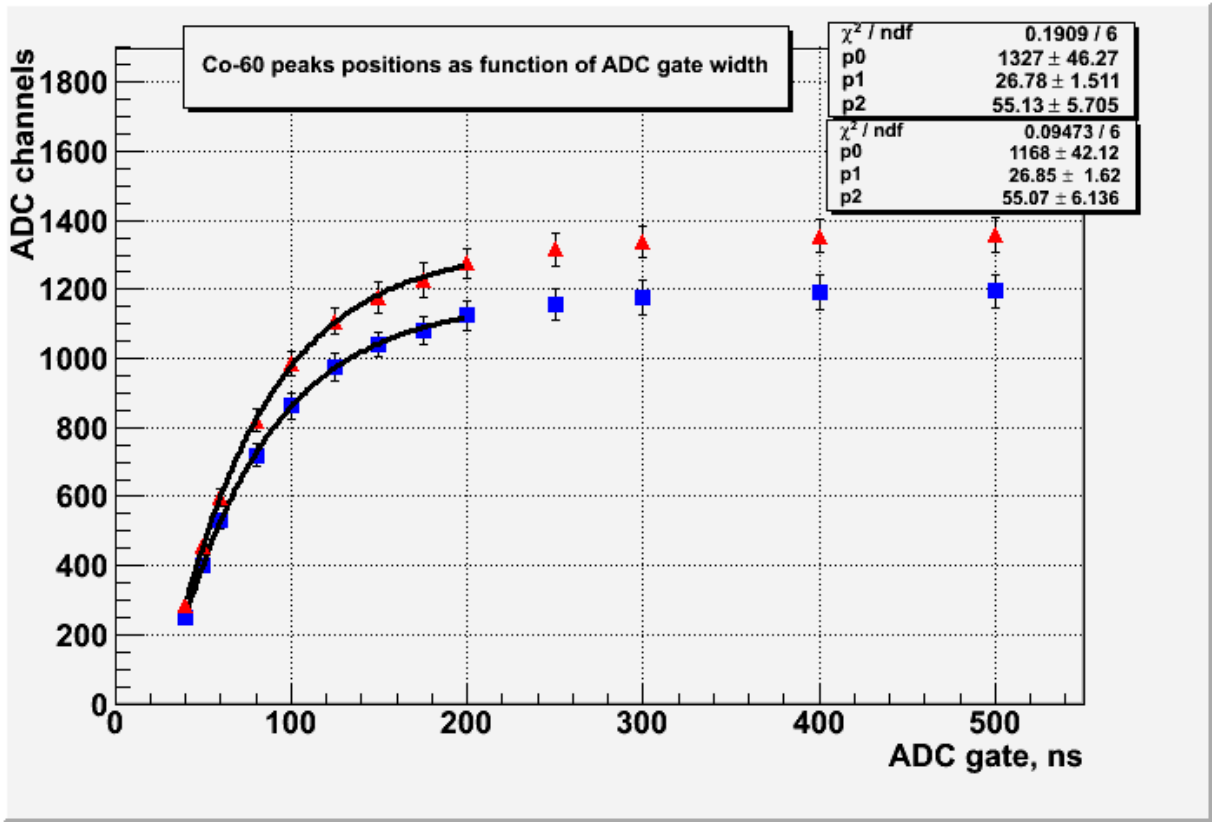
LYSO light output measurement







- ADC gate width varied from 40 ns to 500 ns
- ^{60}Co peaks positions measured for each gate width



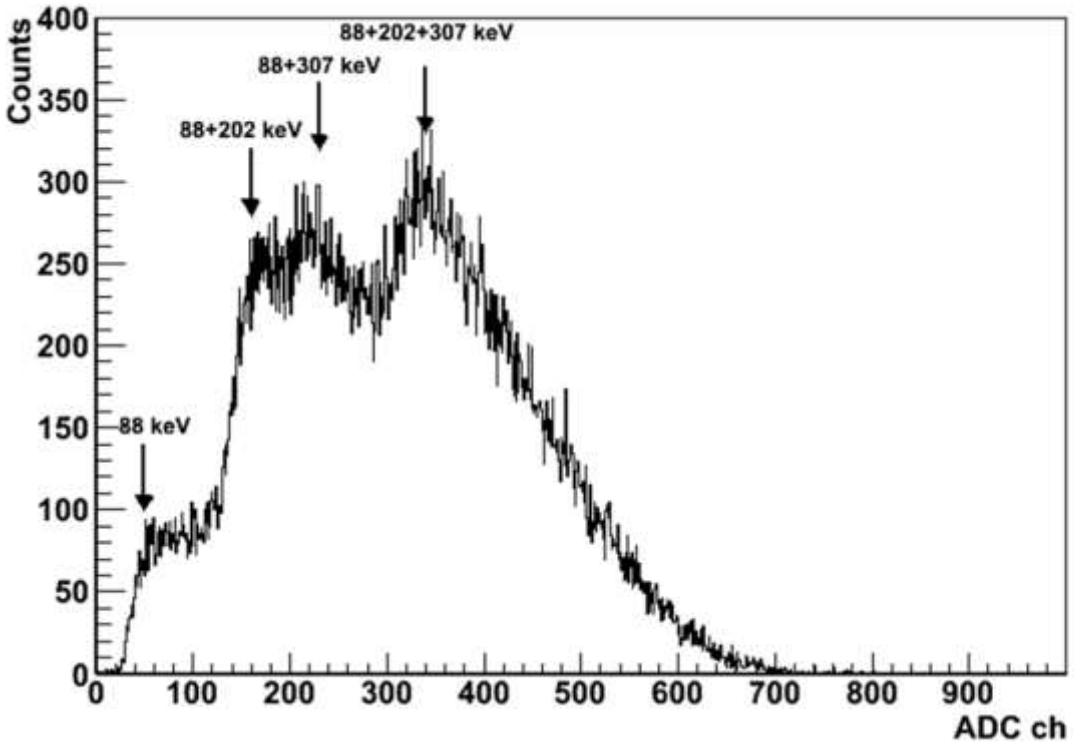
$$A=A_0\{1-\exp((t_0-t)/\tau)\}$$

Tests of 1x1x1 cm^3 LYSO crystal

Preliminary results

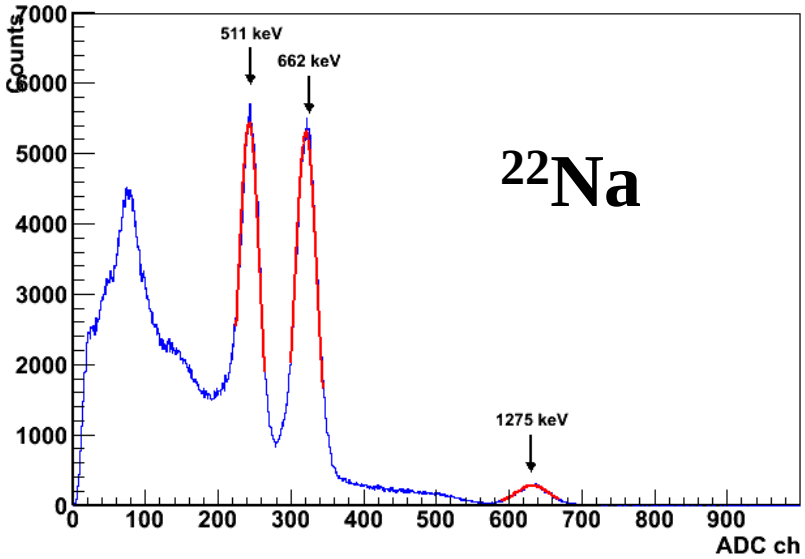
- Test are done with Hamamatsu APD S8664-1010
- Charge sensitive preamp has an integrating time about of 1 μs

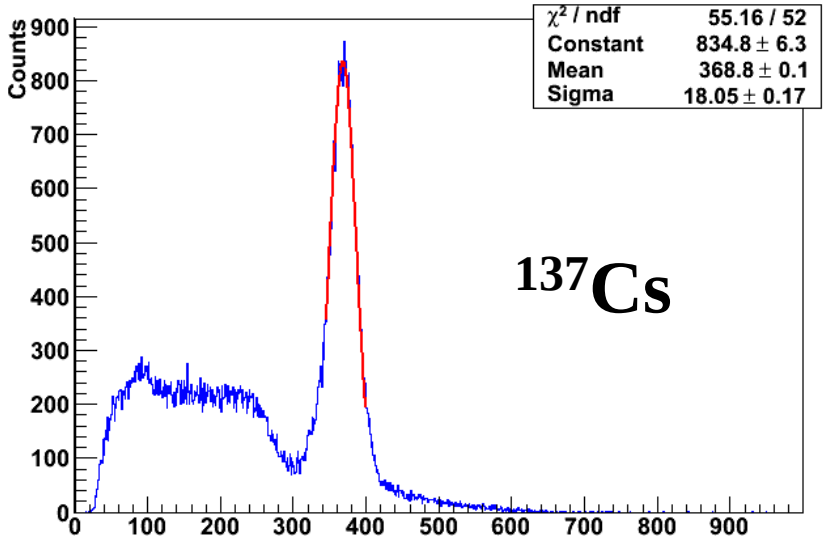
Crystal intrinsic rate

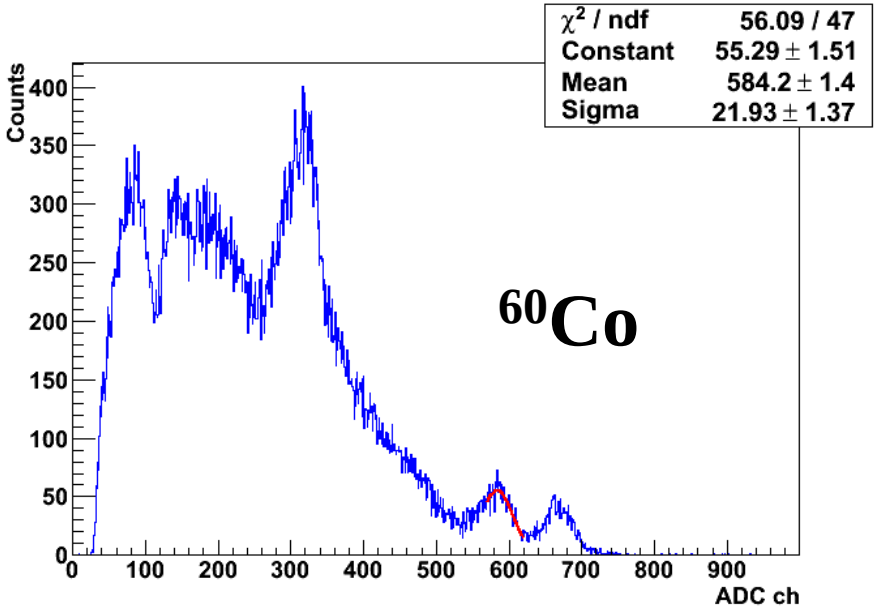


A lot of 202 and 307 keV gammas escape crystal due to its small size

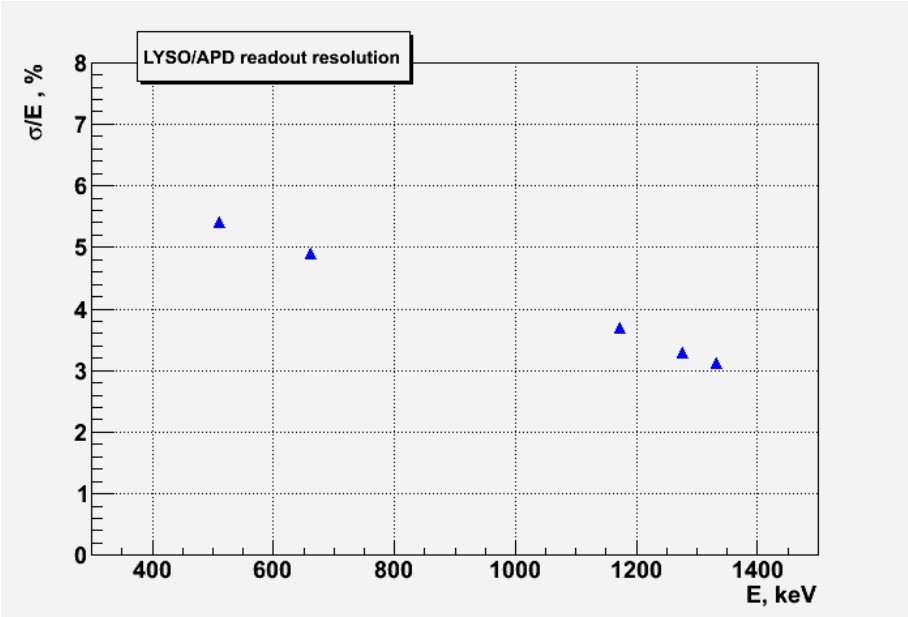
1x1x1 cm^3 LYSO crystal irradiation with ^{22}Na, ^{137}Cs, ^{60}Co

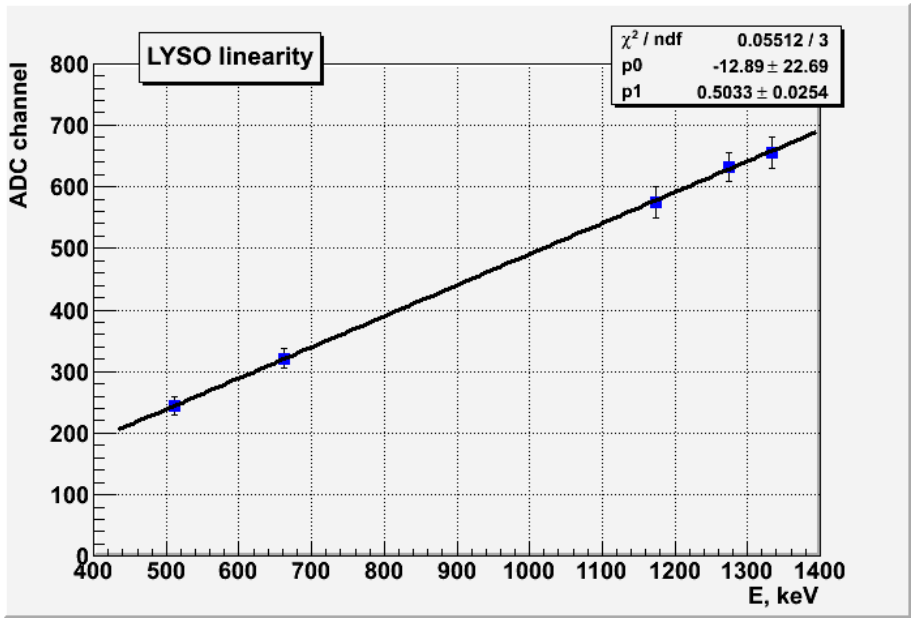






1x1x1 cm^3 LYSO crystal resolution and linearity





Conclusions and future plans

- Test measurements of the Saint-Gobain LYSO crystal 30x30x130 mm^3 have been done employing the PMT EMI9813. A reasonable resolution achieved by excitation of crystal with gammas in the range 500-1330 keV.
- Preliminary test results of 10x10x10 mm^3 LYSO crystal with Hamamatsu APD S8664-1010 look very promising.

Plans:

- ❑ Tests of Saint-Gobain LYSO crystal:
  - with Hamamatsu APDs S8664-1010.
  - Study of light collection uniformity due to different types of wrapping.
  - Tests with Geiger mode APDs (SiPM/MAPD/MPPC)
- ❑ Tests of crystals from ISMA, Kharkov:
  - Optical parameters
  - Resolution, light response uniformity, etc.

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