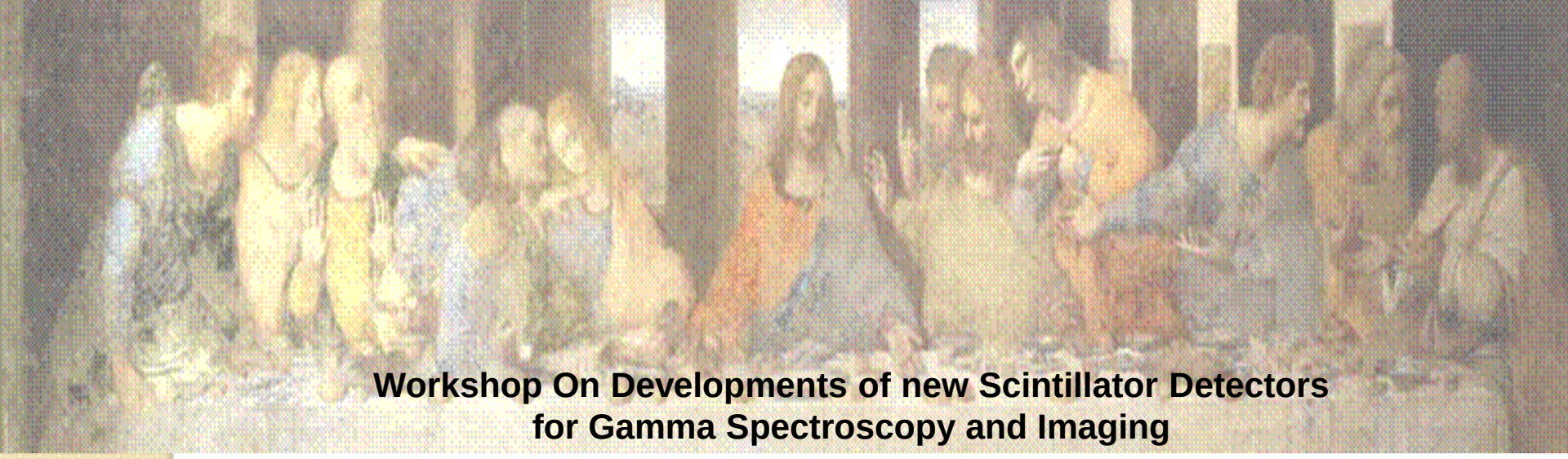


Workshop On Developments of new Scintillator Detectors
for Gamma Spectroscopy and Imaging

A High Resolution Phoswich: $LaBr_3(Ce)$ & $LaCl_3(Ce)$ possible solution for the R3B calorimeter

O. Tengblad, M. Carmona, J.A. Briz, M.J.G Borge, A. Perea

Instituto de Estructura de la Materia CSIC-Madrid

H. Johansson & T. Nilsson

Chalmers University of Technology, Göteborg, Sweden

OUTLINE

1. FAIR – NUSTAR – R3B
2. CALIFA calorimeter
3. PHOSWICH: CHARACTERISTICS

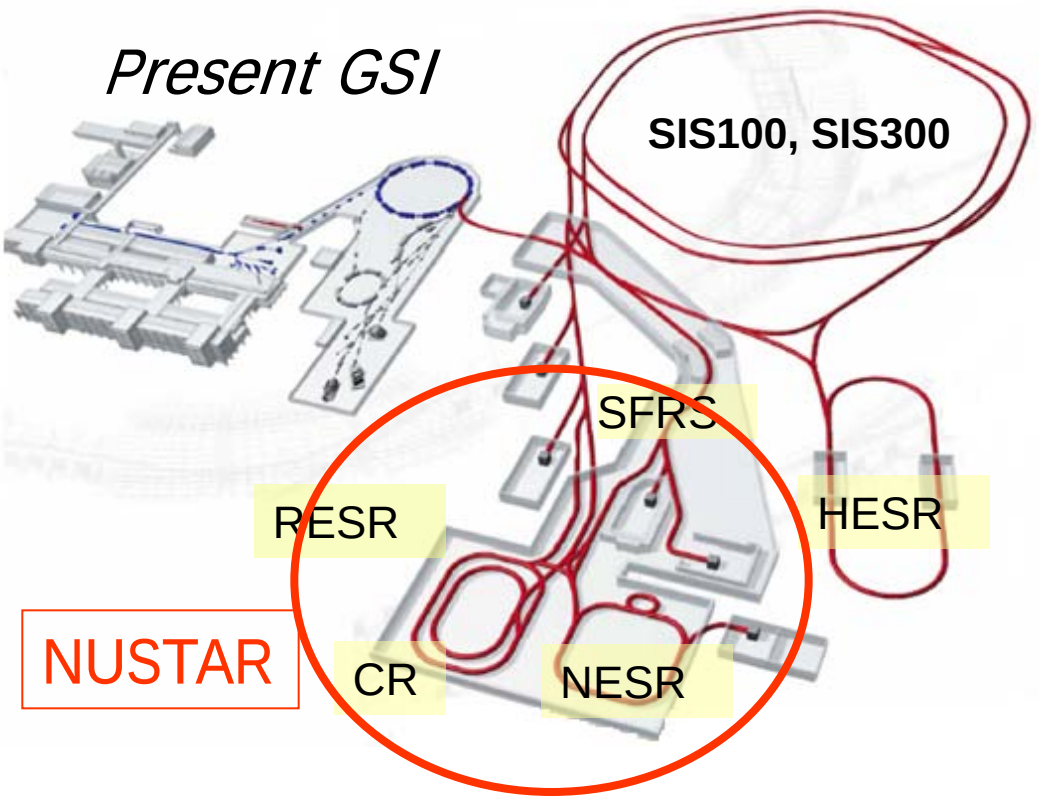
   a) SIMULATIONS

   a) EXPERIMENT
   - Sources
   - γ
   - protons

4. Future Plans
5. Acknowledgment

FAIR - Facility for Antiproton & Ion Research @GSI Darmstadt Germany

FAIR:
Beams of stable as well as exotic ions and anti-protons up to an energy of 30 GeV/u



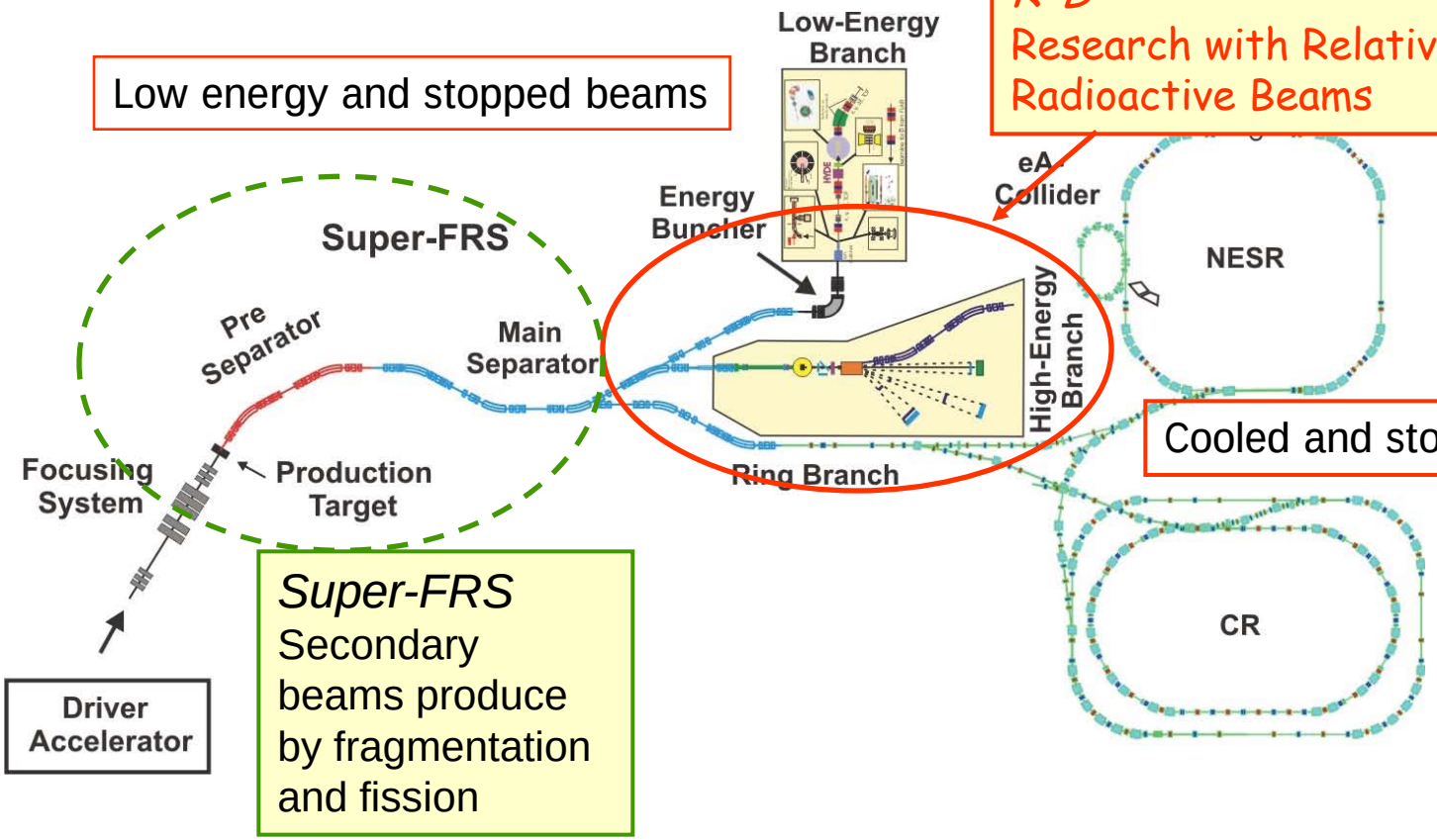
NUSTAR – a facility for NUclear STructure & Astrophysis Research

R³B collaboration:
50 institutes
180 scientists

Superconducting Fragment Separator
- High Energy Reaction Set-up
- Multi-Storage Rings
- Energy bunched and stopped beams

Low energy and stopped beams

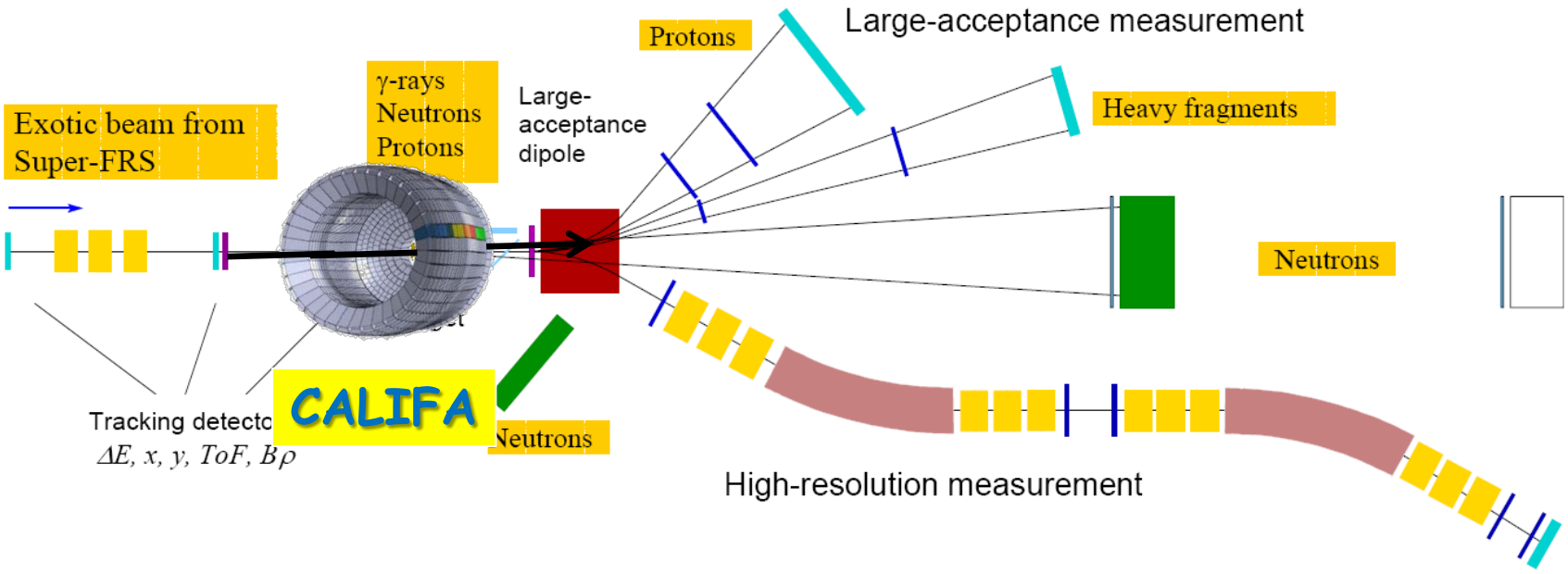
R³B
Research with Relativistic Radioactive Beams



Cooled and stored beams

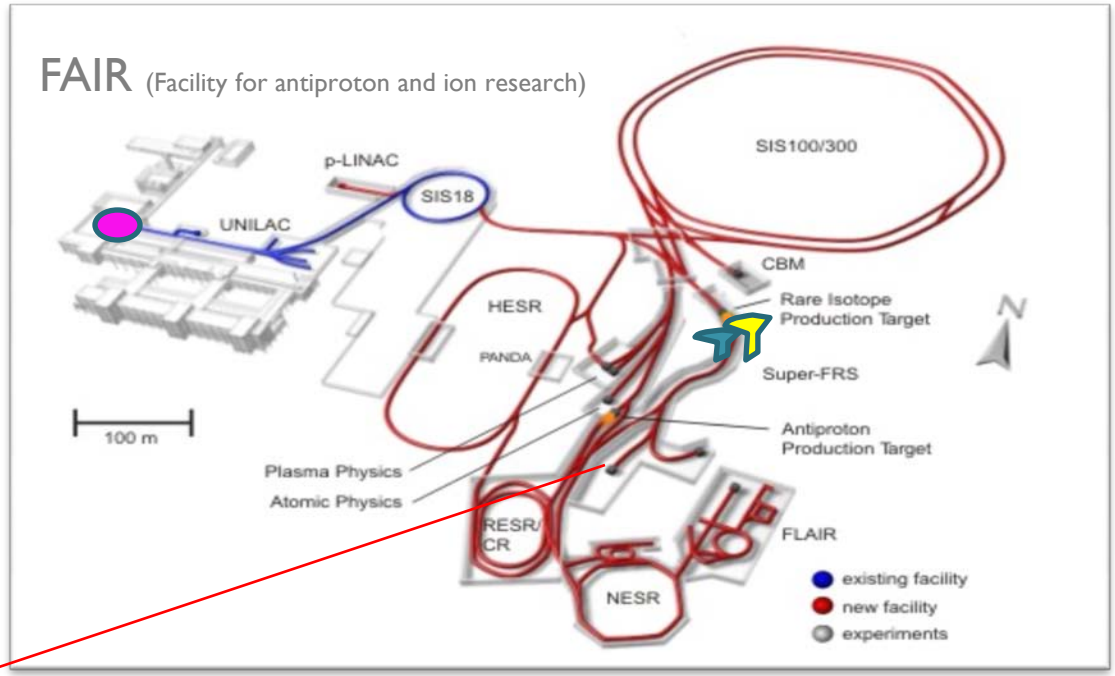
Super-FRS
Secondary beams produce by fragmentation and fission

Reactions using Relativistic Radioactive Beams

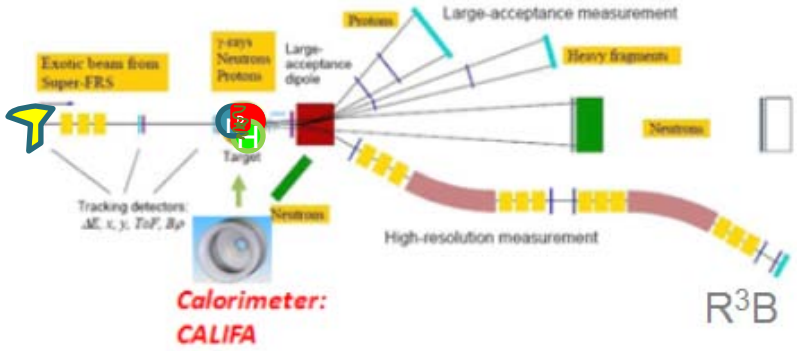


- A universal fixed-target experiment for complete (charged particles, neutrons, gamma rays) inverse-kinematics reactions with relativistic RIBs (~300 – 1500 MeV/u), fully matched to the Super-FRS production method
- Experiments with the most exotic (<1 ion/s) and short-lived nuclei - exploring the isospin frontier at and beyond the drip-lines – using a long range of reaction classes
- Concept built on existing ALADIN-LAND experiment at GSI

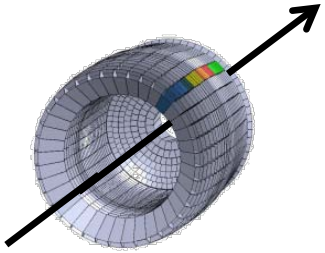
How does it work



R^{3}B



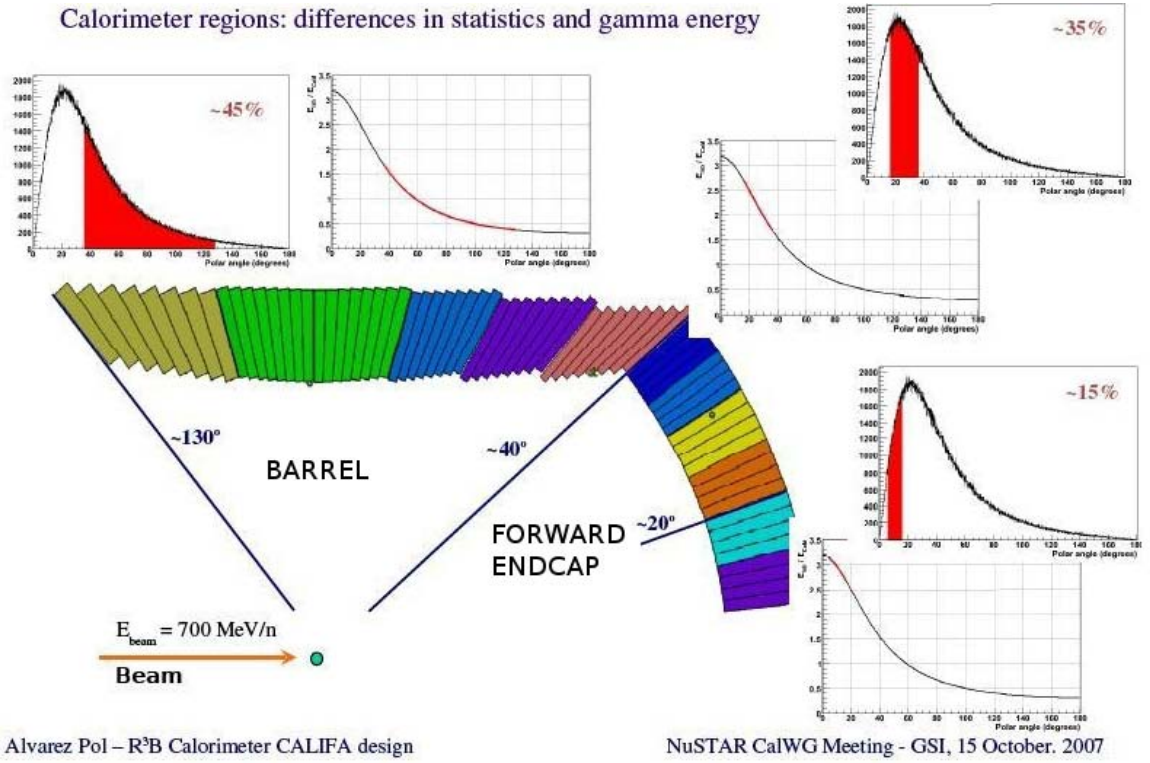
CALIFA CALORIMETER



Detect γ (50 keV – 25 MeV) with energy resolution < 5%)

Barrel: Region from ~40° up to 130° in polar angles

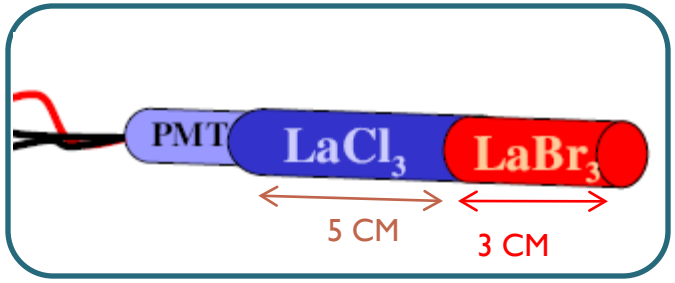
Forward endcap: From ~ 7° up to ~40°

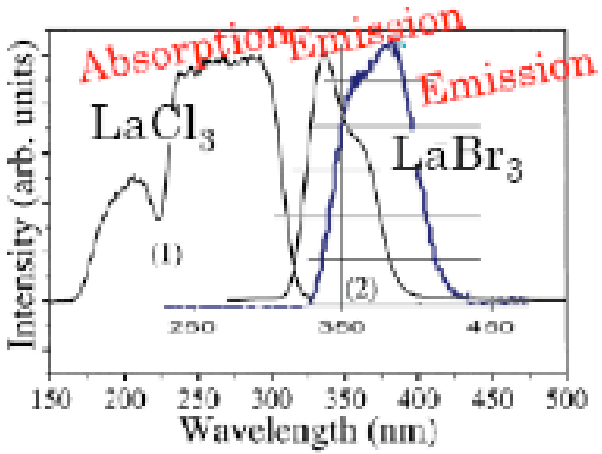


PHOSWICH

In the Forward direction the high energy and the exponential behavior of the Lorentz boost makes a special solution needed; we have looked into a novel solution using new high resolution Scintillator material and specially to use:

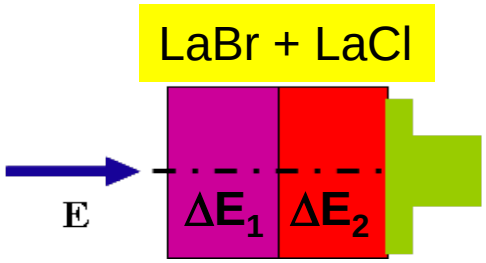
Two scintillator crystals in a phoswich configuration with a common readout





Materials	Energy Resolution (at 662 keV) (%)	Light yield (photons/ keV γ)	Decay time (ns)	$\lambda_{emision}$
$LaBr_3$	2.9	63	16	380 nm
$LaCl_3$	3.8	49	28	350 nm

Why Phoswich

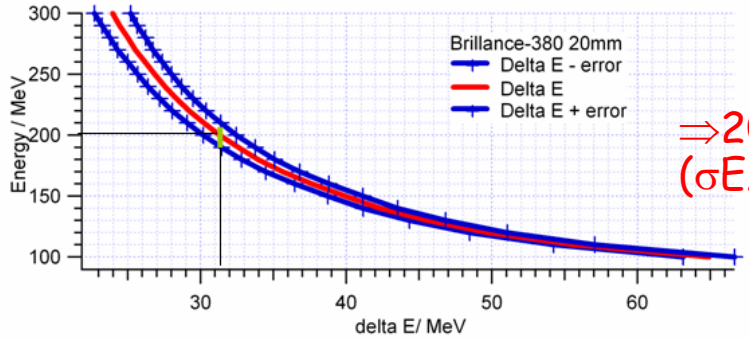


$$-\frac{dE}{dx} = Kz^2\frac{Z}{A}\frac{1}{\beta^2}\left[\frac{1}{2}\log\frac{2m_ec^2\beta^2\gamma^2T_{max}}{I^2} - \beta^2\right]$$

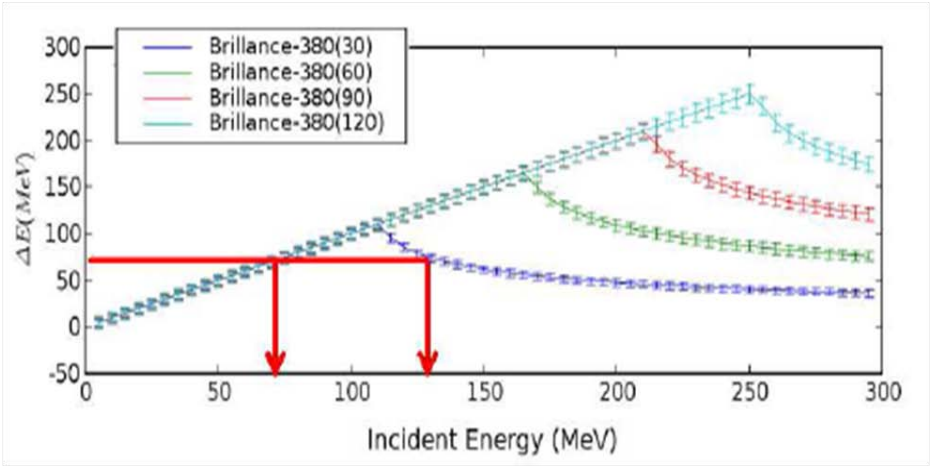
$E \rightarrow \Delta E_1+\sigma(\Delta E_1) \qquad \Delta E_2+\sigma(\Delta E_2)$

$E = f(\Delta E_1) + g(\Delta E_2)$

Ep= 200MeV → 20 mm LaBr → ΔE = 31 1 MeV

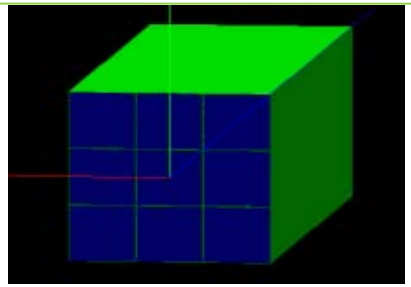


⇒200 10MeV
(σE/E=5%)



- **Protons:**
  Using two ΔE-detectors one can determine the full proton energy with a resolution of <5%.
- **Gammas: Second detector placed to solve the ambiguity on the signal**

SIMULATIONS γ



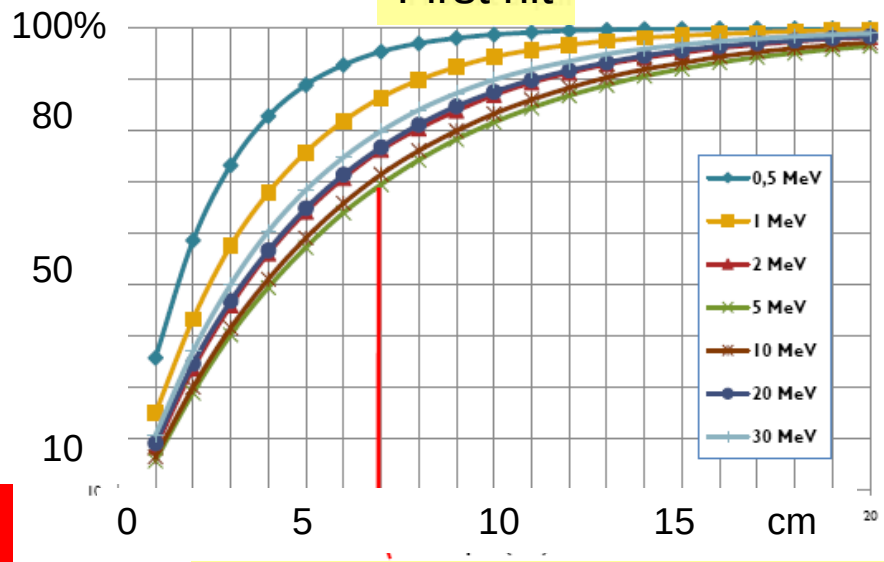
Question to be answered:

- Depth of first interaction
- Depth @ 90% photopeak efficiency
- How many neighbouring crystals are being hit?

Simulation codes

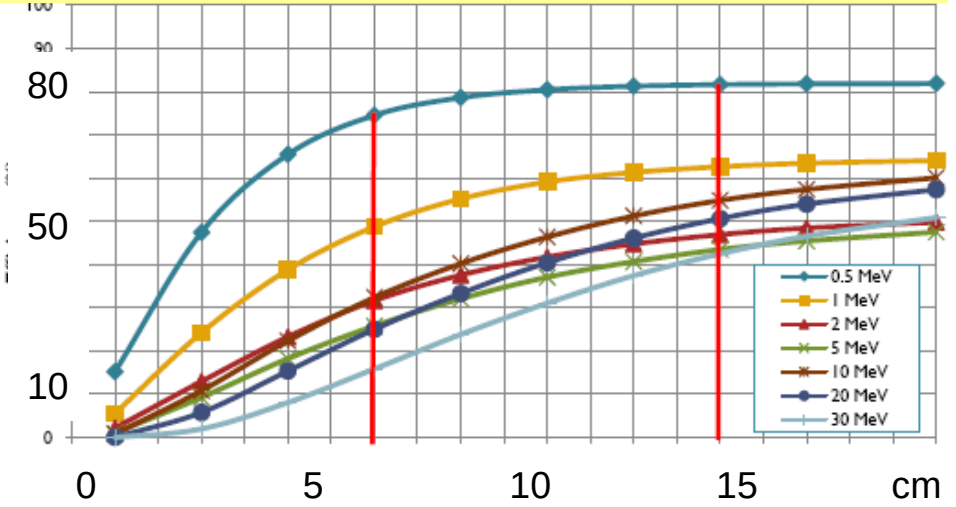
- SRIM --- GEANT4 --- MCNPX Monte Carlo N-Particle eXtended code

First hit

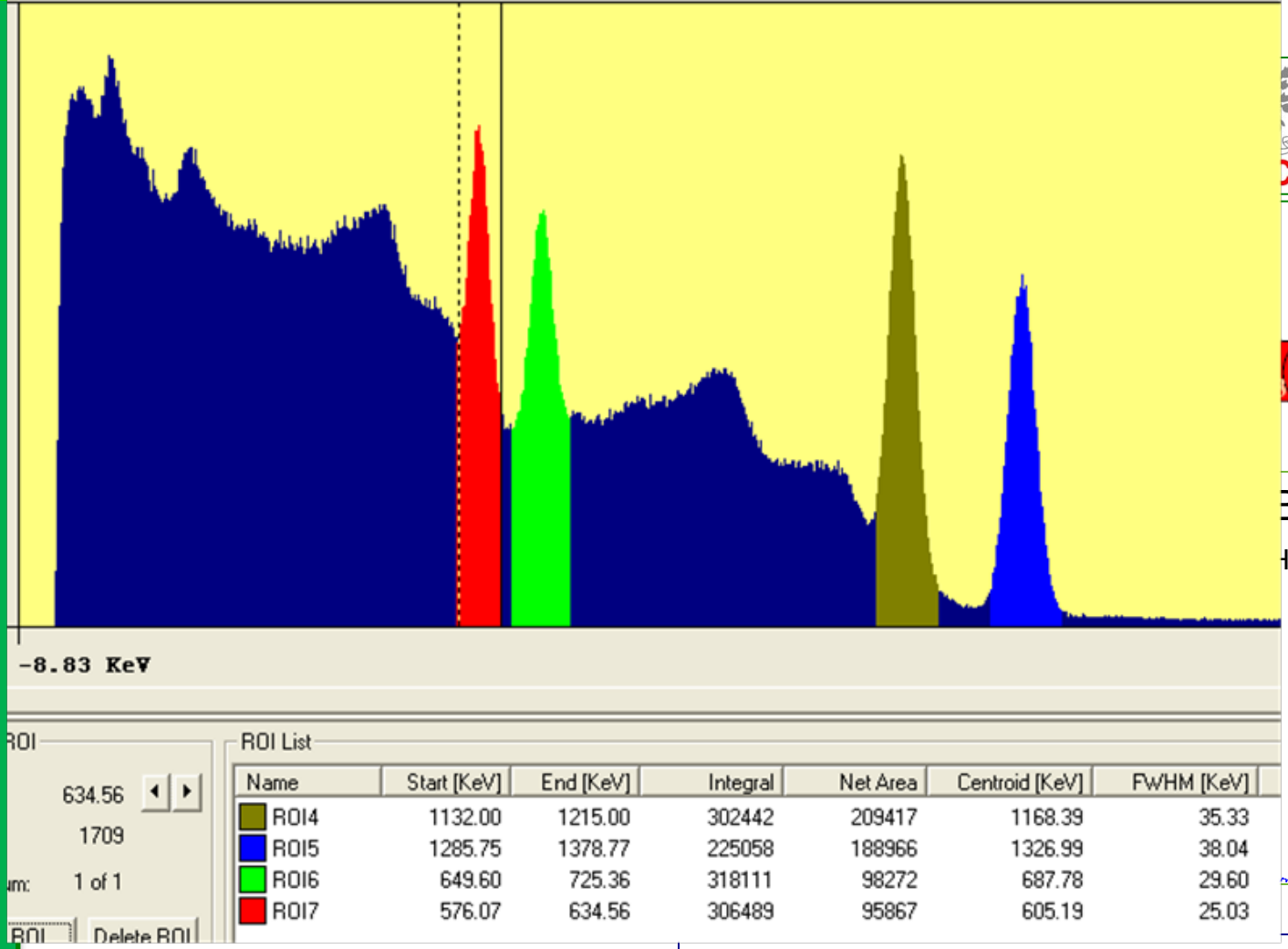


@7 cm 70 % of incident beam is detected

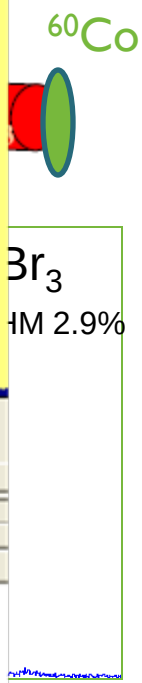
90% Photopeak efficiency vs crystal length



>15 cm has NO influence on detection efficiency



Name	Start [KeV]	End [KeV]	Integral	Net Area	Centroid [KeV]	FWHM [KeV]
ROI4	1132.00	1215.00	302442	209417	1168.39	35.33
ROI5	1285.75	1378.77	225058	188966	1326.99	38.04
ROI6	649.60	725.36	318111	98272	687.78	29.60
ROI7	576.07	634.56	306489	95867	605.19	25.03

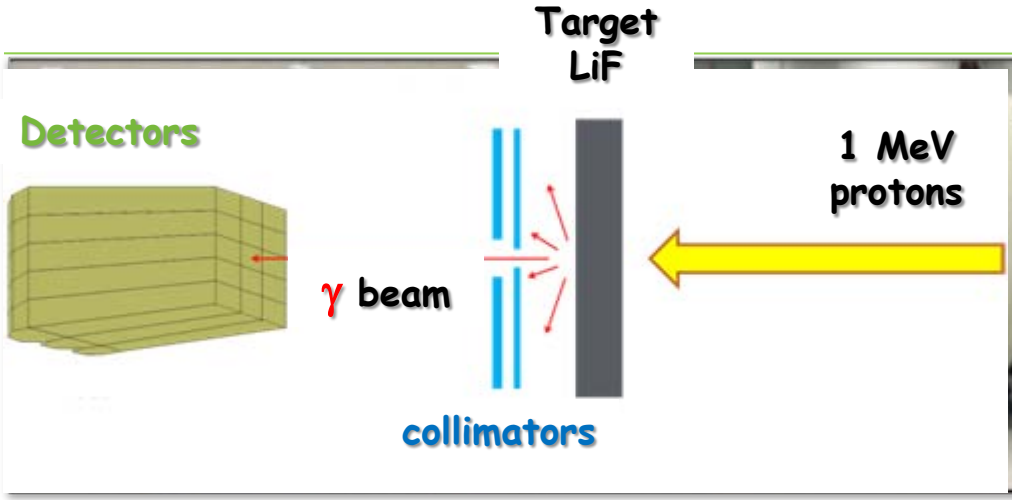


^{60}Co Eγ 1332 MeV
1173 MeV

Saint Gobain LaBr 20x30 mm
LaCl 20x50 mm

Hamamatsu R5380 8 stage
Hamamatsu Modified Base +HV

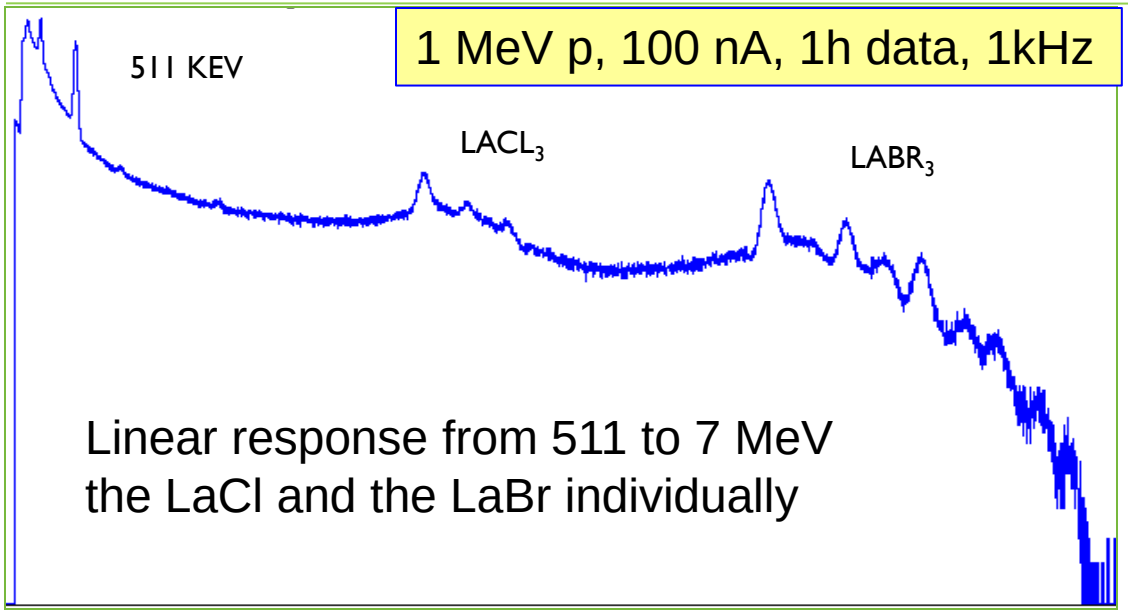
EXPERIMENT @ CMAM 5MV tandem



$^{19}F(p,\alpha\gamma)^{16}O$ **TARGET: TEFLON**

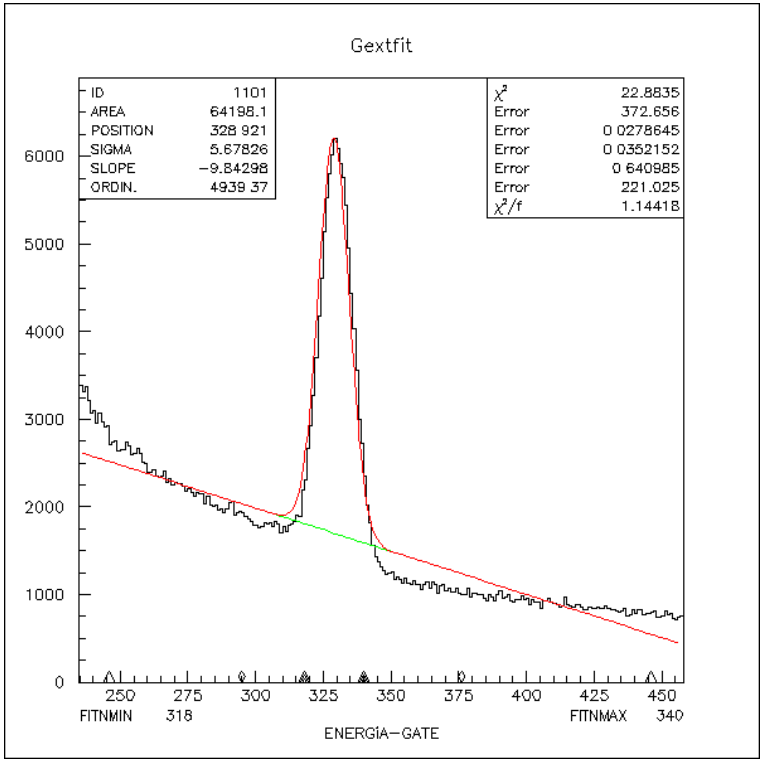
	E_p (MeV)	E_γ (MeV)	
^{19}F	1	6.129	RESONANCE
		5,618	SINGLE ESCAPE
		5,107	DOBLE ESCAPE
		0,511	

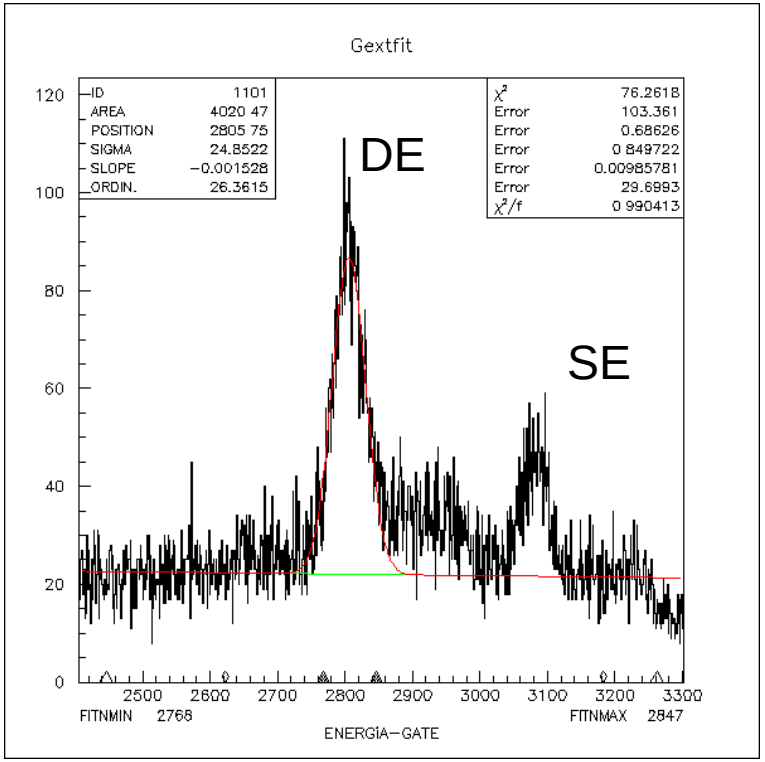
γ RESOLUTION @ 6 MeV



CRISTAL	ENERGIA (MeV)	RAZON	RESOLUCION	AREA
$LaBr_3$	6.129	Resonance	1.9 %	7659
	5618	SE	2 %	25435
	5107	DE	2 %	61712
	511	Annhilation	4 %	1304026
$LaCl_3$	6.129	Resonance	2.9 %	5051
	5618	SE	3.7 %	25027
	5107	DE	3.7 %	36755

PHOSWICH @ 6 MeV γ





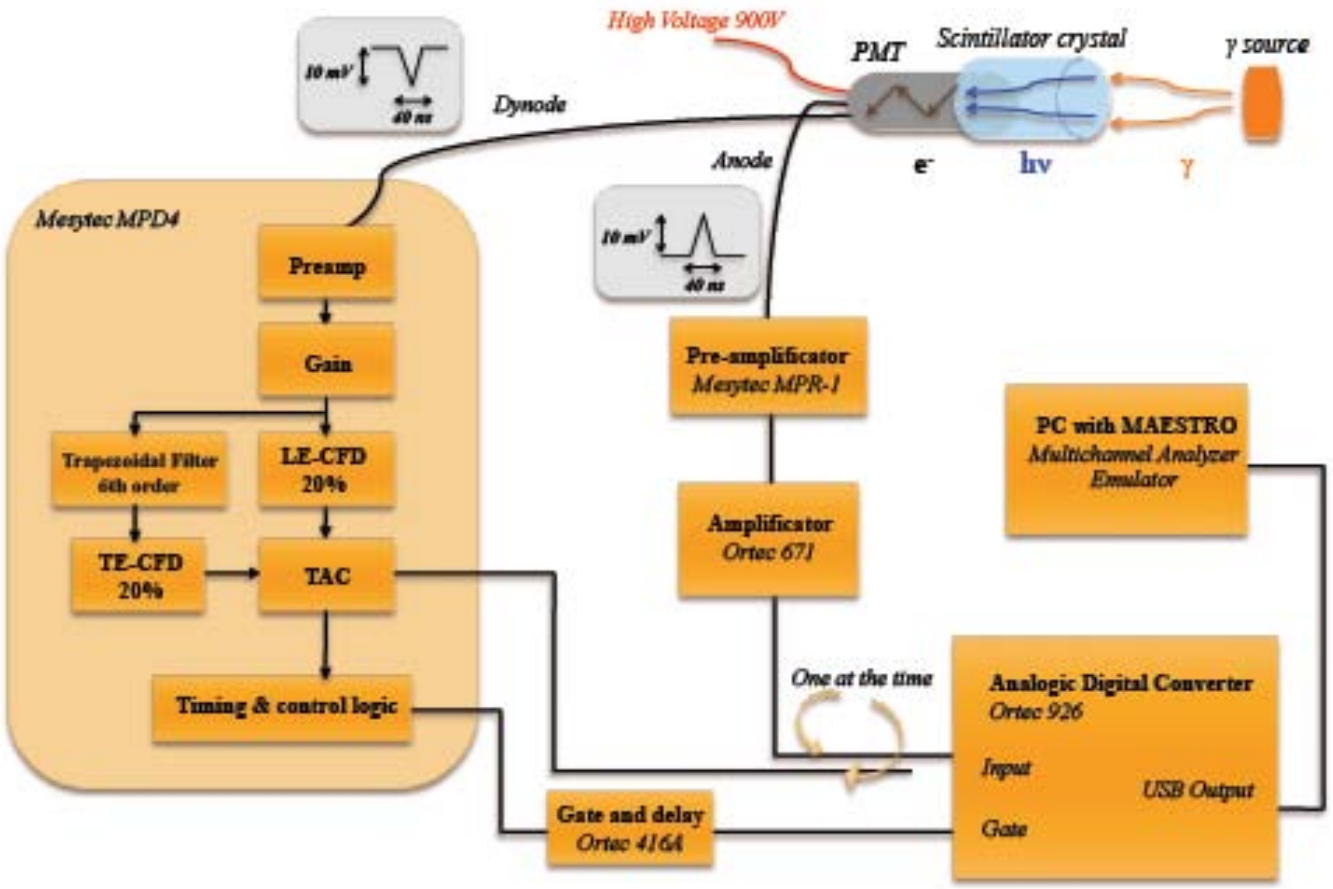
511 KeV annihilation

4.0% FWHM

5107 KeV (6129 – 2*511)

2,0% FWHM

Separate the time response



1) Sources: Standard coincidence chain: TAC to gate the MCA
2) CMAM: Listmode data: TAC to VME ADC, MIDAS DAQ system

PHOSWICH @ 6 MeV γ

OUTLINE

FAIR NUSTAR

CALIFA

PHOSWICH

SIMULATIONS

EXPERIMENT

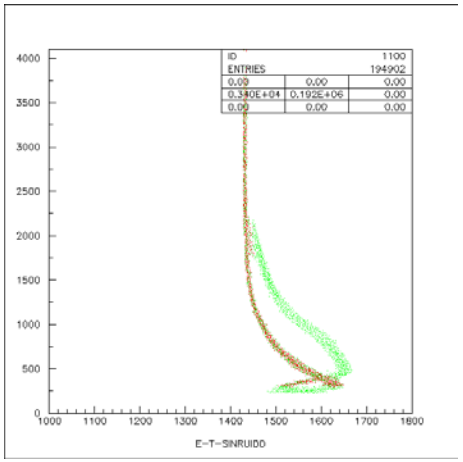
Sources

gamma

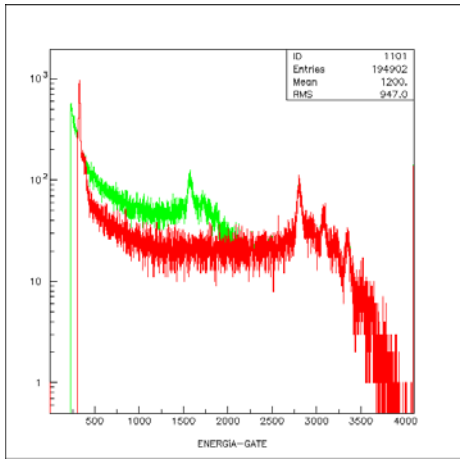
protons

FUTURE PLANS

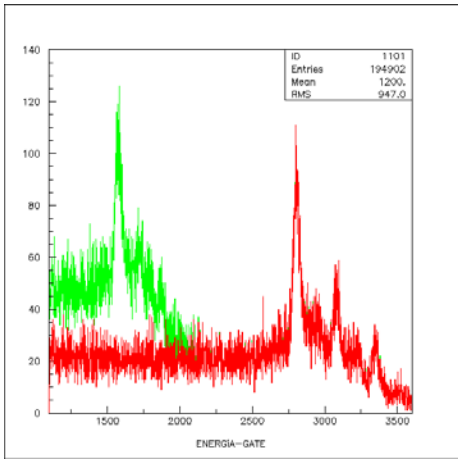
Gate on $LaBr_3$



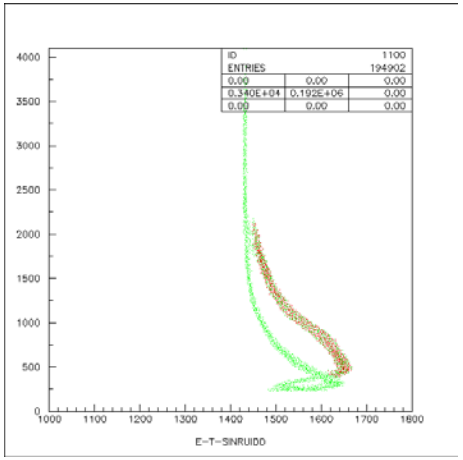
Energy vs Time

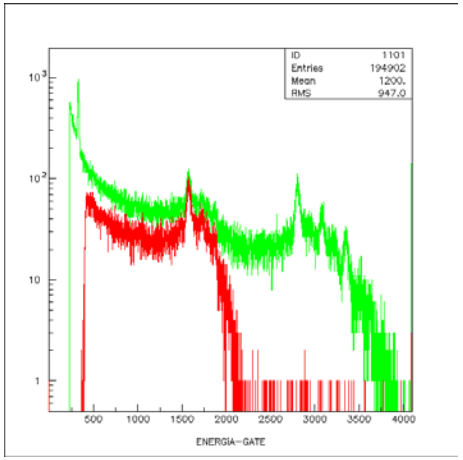


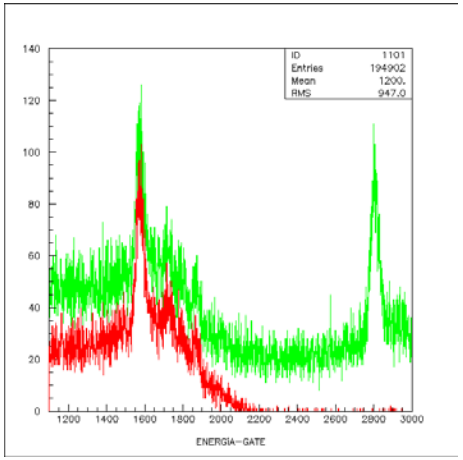
Energy (log)



Energy (lin)







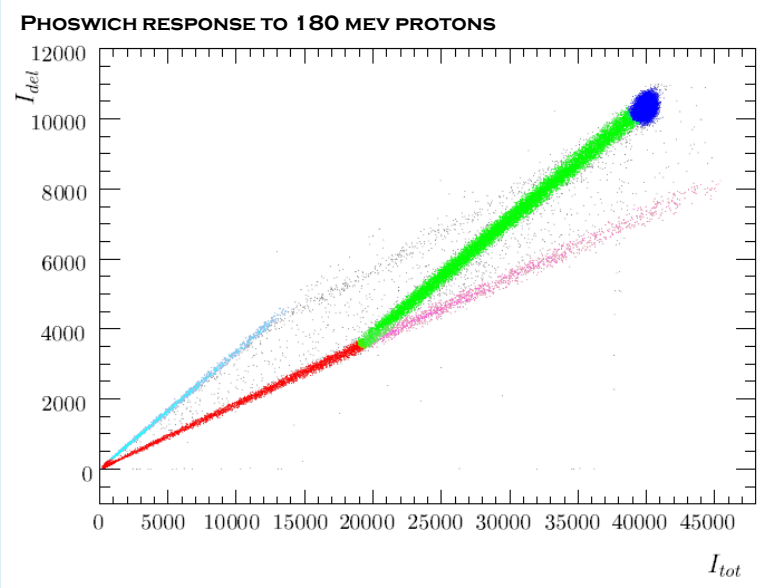
Gate on $LaCl_3$

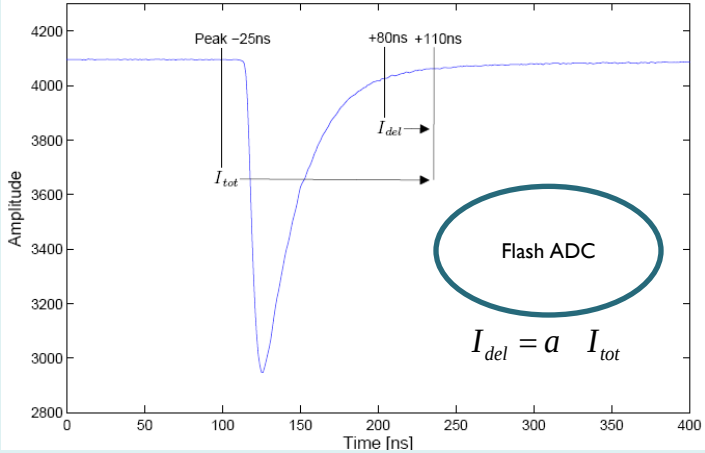
150/180 MeV Protons @ The Swedberg Lab. Uppsala

Two separate Readout systems:

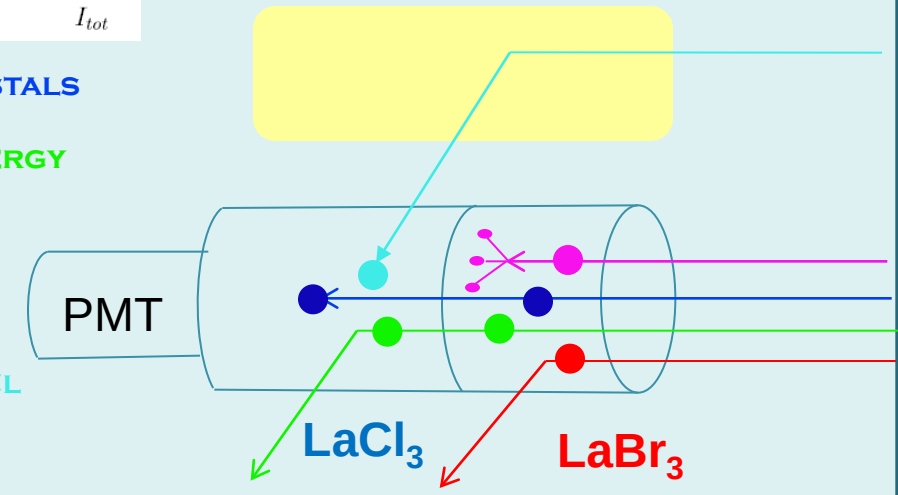
→Dynode →Mesytec MPR1-PMT → Mesytec SCHM-16 →ADC (Energy)
→ Anode → Sampling ADC (timing) **MATACQ32 from M2J**

Phoswich detector response to Ep = 150 & 180 MeV





- PROTON SLOWED DOWN IN THE TWO CRYSTALS
- PROTON ESCAPING LEAVING PART OF ENERGY
- PROTON SCATTERED OUT FROM LaBr
- PROTON STOPPED IN 1ST CRYSTAL
- PROTON SCATTERED IN DIRECTLY ON LaCl
- PILE UP & NOISE



150/180 MeV Protons @ TSU

FAIR NUSTAR

CALIFA

PHOSWICH

SIMULATIONS

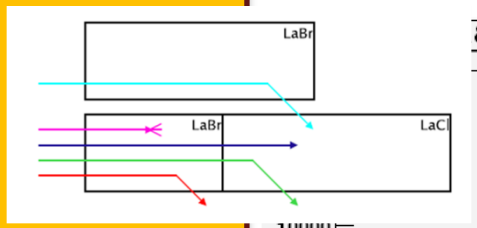
EXPERIMENT

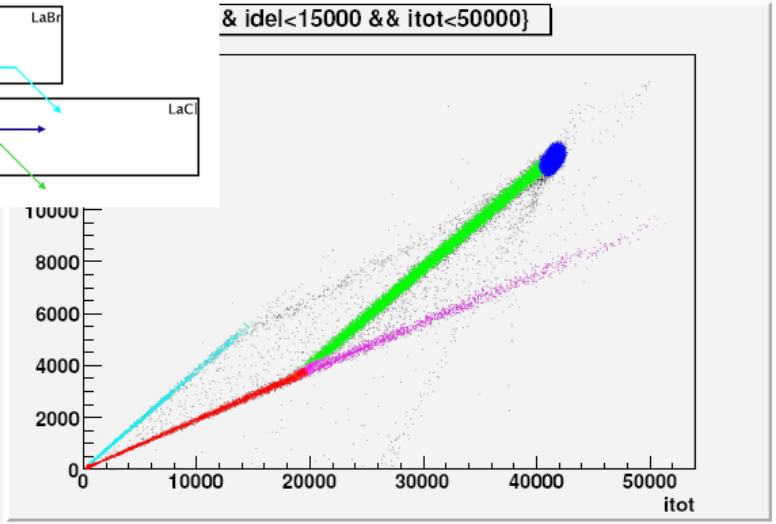
Sources

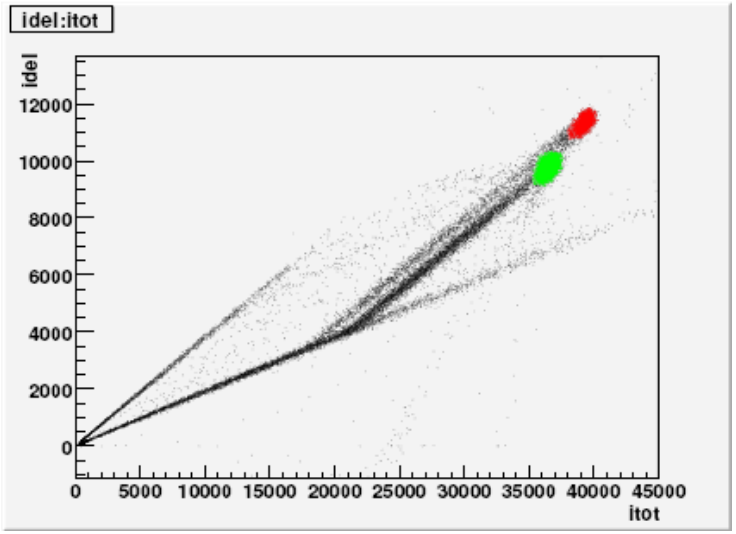
gamma

protons

FUTURE PLANS

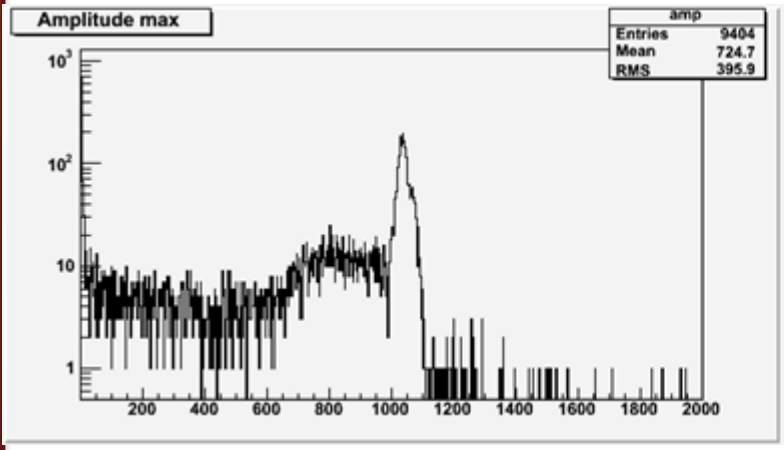


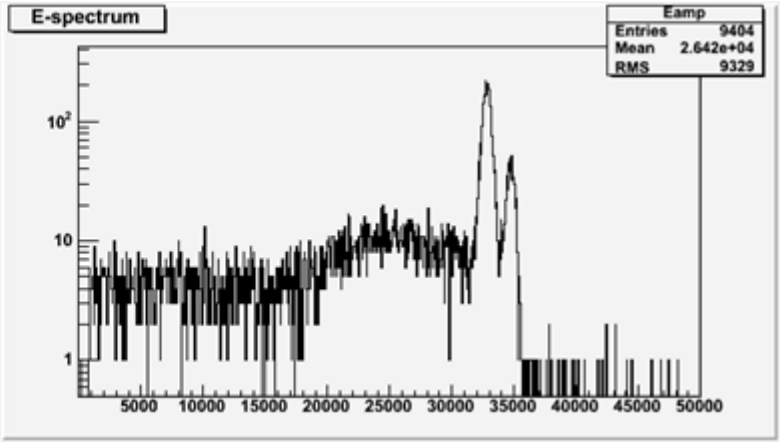




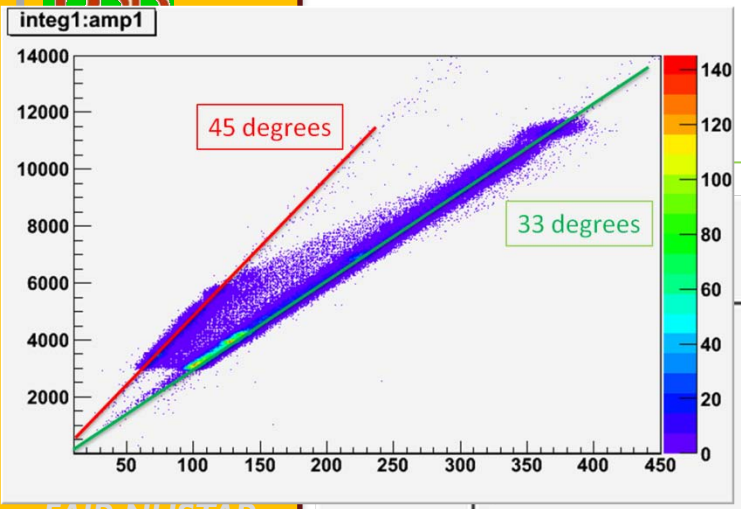
Sampling ADC 1% resolution

Shaper 0.6% resolution

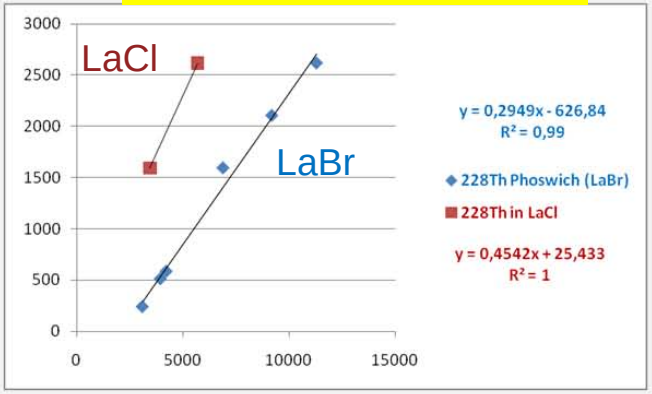




228Th gamma source
Eγ = 200 -2600 KeV



Energy vs channel



LaBr/LaCl + PM tube + Digital readout

Dynamic range 100 KeV γ – 200 MeV p

PM tube at 700V instead of optimum 1500V

OUTLIN

FAIR NUS

CALIFA

PHOSWI

SIMULATIC

EXPERIME

Sources

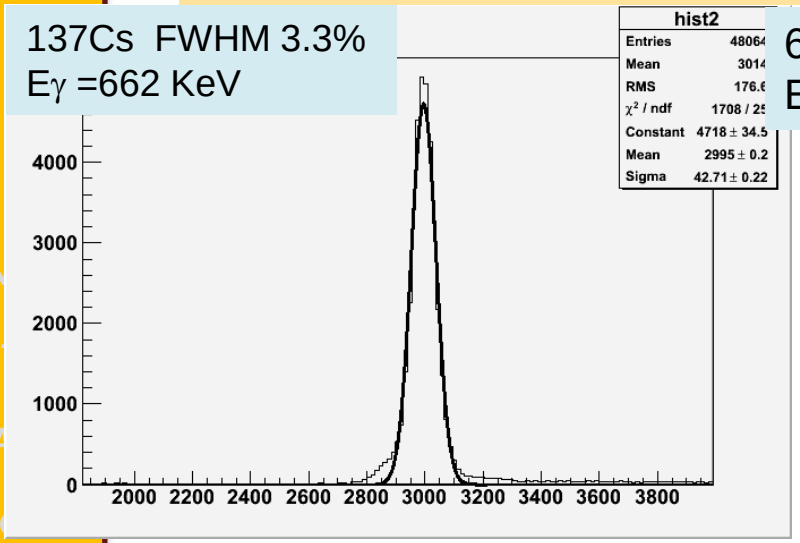
gamma

protons

FUTURE PL

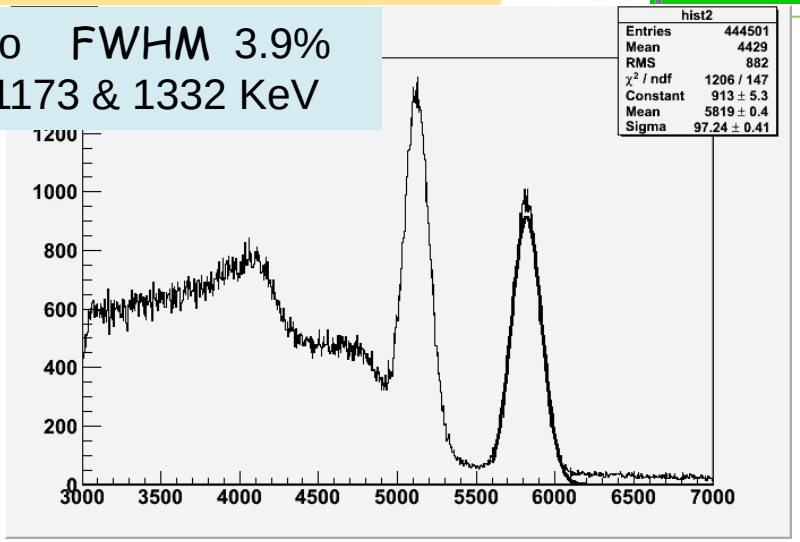
137Cs FWHM 3.3%

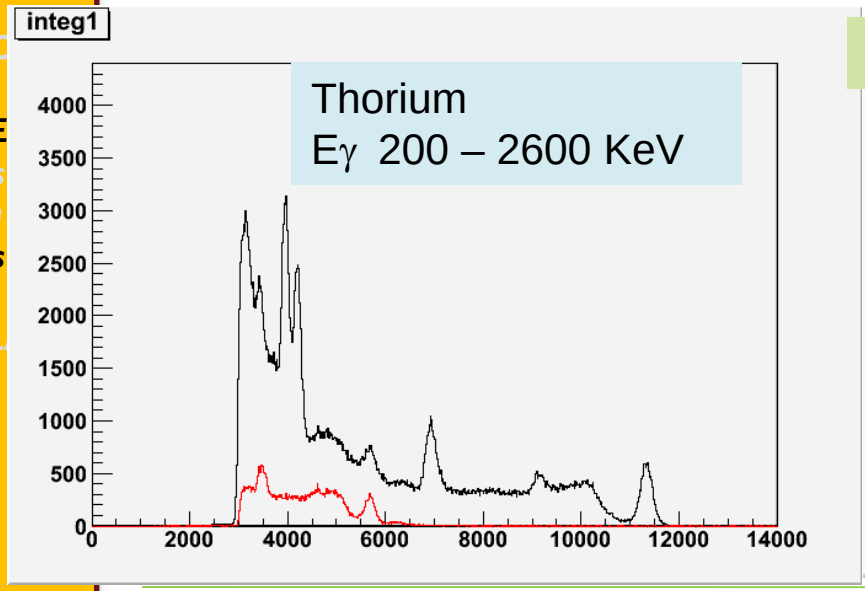
Eγ =662 KeV



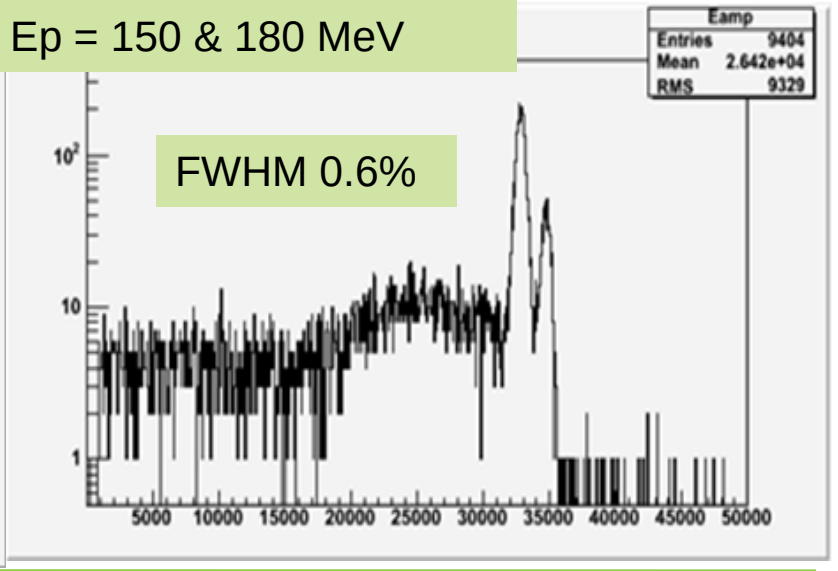
60Co FWHM 3.9%

Eγ: 1173 & 1332 KeV





Ep = 150 & 180 MeV

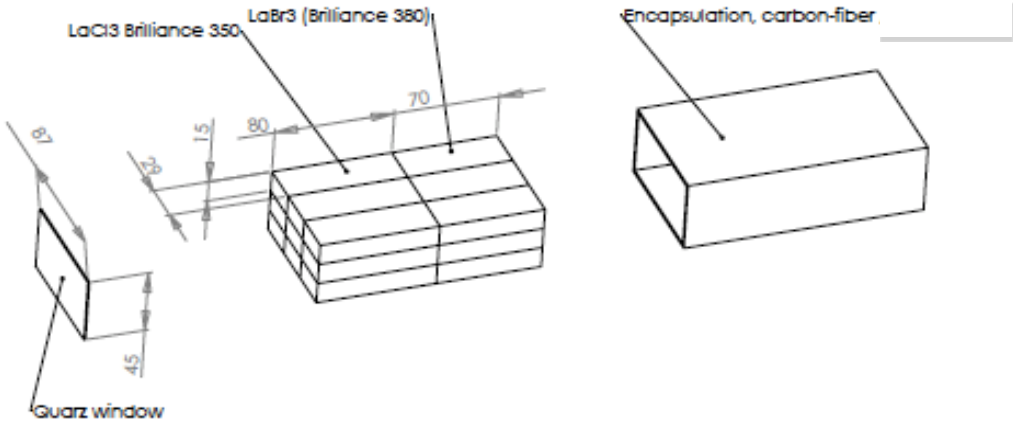


FUTURE PLANS

Phoswich:

•Realistic simulations of Phoswich module for CALIFA front cap

* We asked for money (2010-2012) to build a 9 crystal prototype of realistic crystal shapes



CALIFA

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