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Consejo Superior de Investigaciones Científicas

Grupo de Física Nuclear Experimental
IEM

I[st] Topical Workshop on Modern Aspects in Nuclear Structure

Advances in Nuclear Structure with arrays including new scintillator detectors

BORMIO 22 - 25 February 2012

The gamma proton calorimeter for R^{3}B

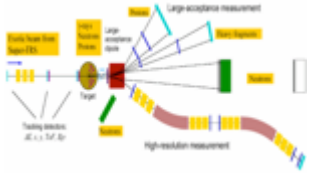
O. Tengblad IEM-CSIC

For the CALIFA WG and the R3B collaboration

Instituto de Estructura de la Materia, CSIC, E-28006 Madrid, Spain

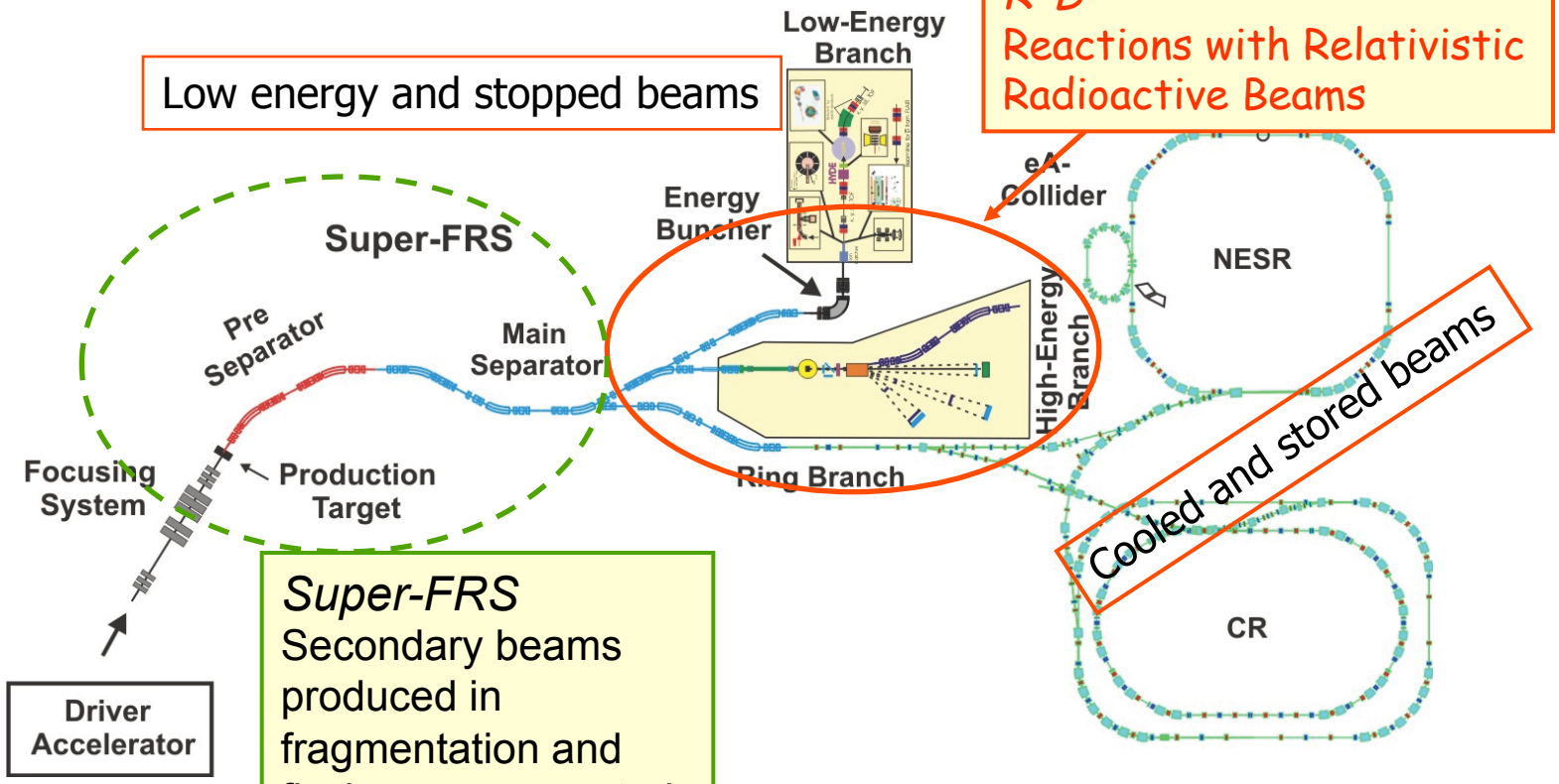
- General introduction to R3B & CALIFA
- CALIFA
- CEPA Califa End Cap Array & Phoswich concept
- Simulations for Phoswich

NUSTAR – a facility for NUclear STructure & Astrophysis Research



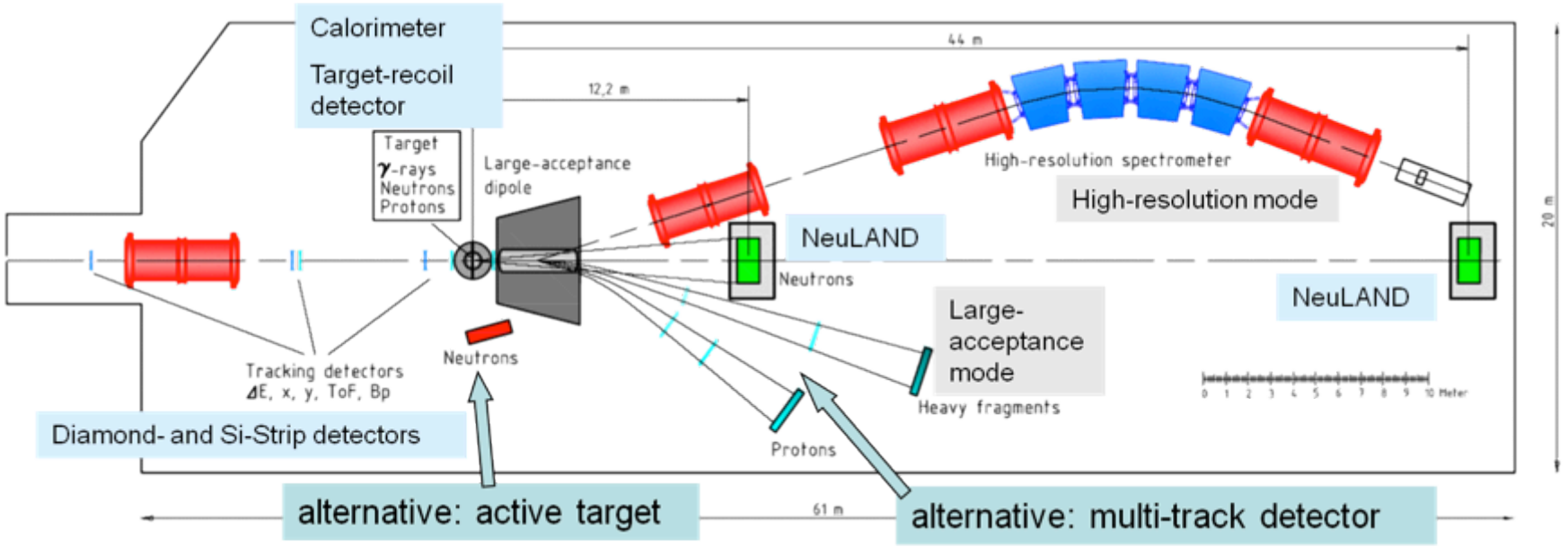
Low energy and stopped beams

R^3B
Reactions with Relativistic Radioactive Beams



Super-FRS
Secondary beams produced in fragmentation and fission are separated and directed to experimental hall

R³B: Reactions with Relativistic Radioactive Beams



Kinematically complete measurement of reactions with high-energy secondary beams

- **Nuclear Astrophysics**
- **Structure of exotic nuclei**
- **Neutron-rich matter**

- A universal fixed-target experiment for complete inverse-kinematics reactions with relativistic RIBs (~300 – 1500 MeV/u),
- Experiments with the most exotic (<1 ion/s) and short-lived nuclei - exploring the isospin frontier at and beyond the drip-lines –
- Concept built on existing ALADIN-LAND experiment at GSI

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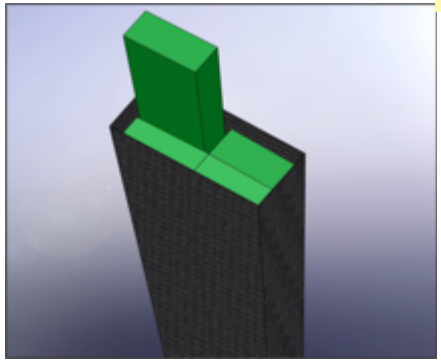
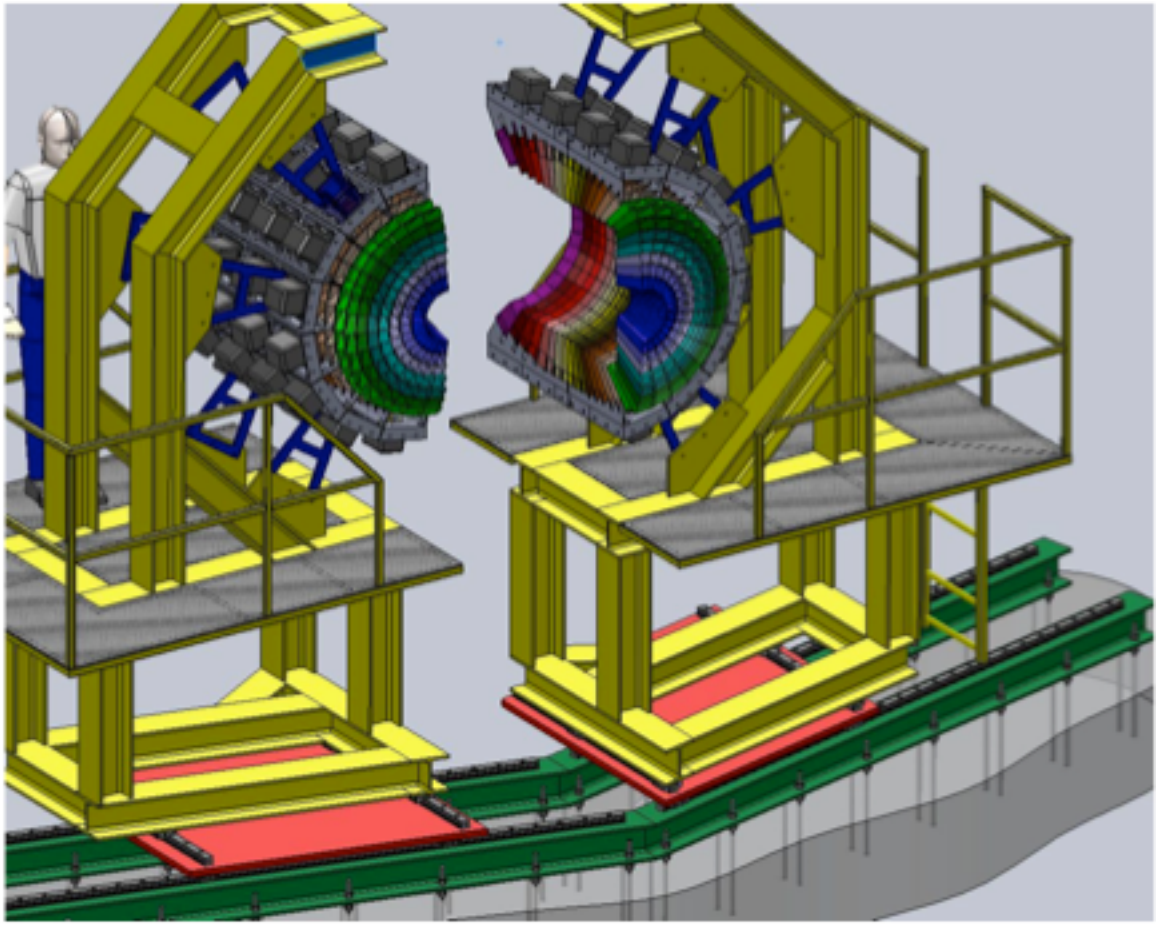
CALIFA

Gamma/proton calorimeter surrounding the reaction target of R^3B





Technische Universität München

TU Darmstadt

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CALIFA – design consideration

- **High-resolution γ spectrometer, relatively low-energy γ-rays (up to 2 MeV), consequently with low multiplicity (2-3). The energy resolution will be in this case the most critical parameter of CALIFA. This value has been set to be of ΔE/E < 6% for 1 MeV , which allows to distinguish most of the simple gamma cascades that come from the de-excitation of light exotic nuclei.**

knock-out reactions employing light, radioactive beams → highly Segmented

- **γ - calorimeter, very energetic γ-rays (up to 10 MeV) and associated with fragmented decays (high-multiplicity events). In this case the key parameters will be its Total absorption (intrinsic photopeak efficiency), sum energy and multiplicities. A typical reaction that will profit from**

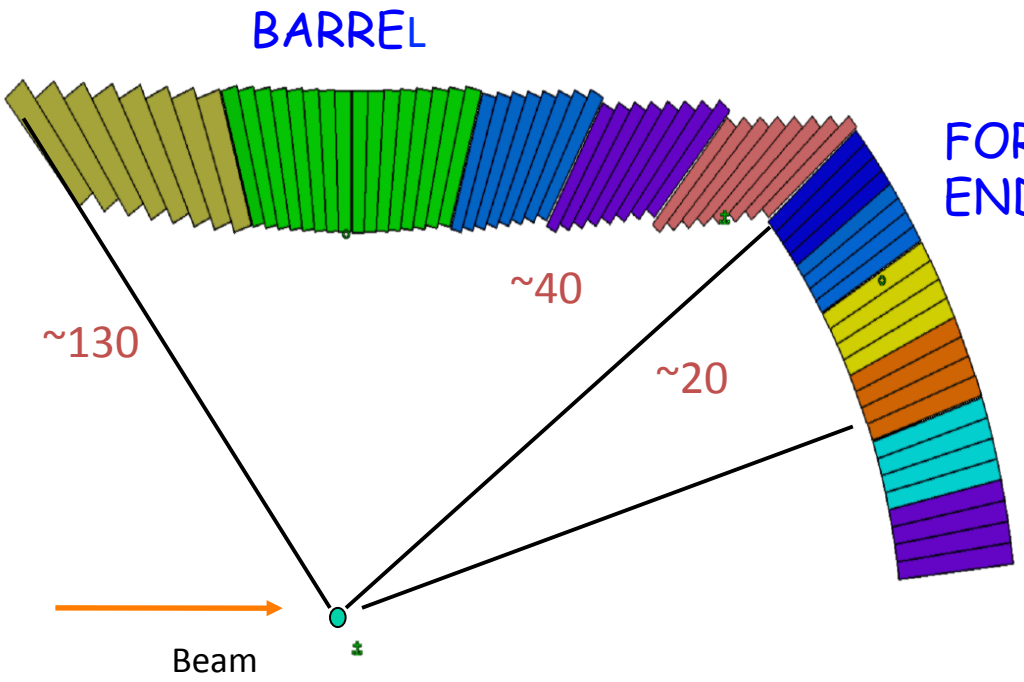
pygme (or giant)-resonance decays → addback, little dead material

- **Hybrid detector simultaneously good calorimetric properties together with high-resolution for highly energetic light charged particles (protons up to 300 MeV)**

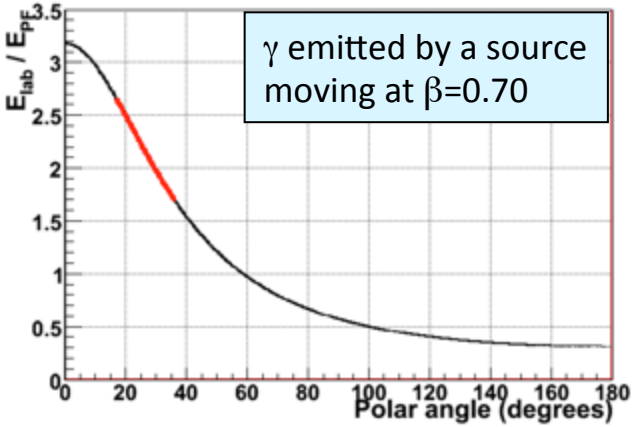
quasi-free scattering (p,2p),(p,pn)…. → good energy resolution + huge dynamic range
γ & p → Time-over-threshold

Design of CALIFA

Kinematic considerations



Detect with good energy resolution & high efficiency
γ < 30 MeV
p < 300 MeV



High energy reaction → forward emission

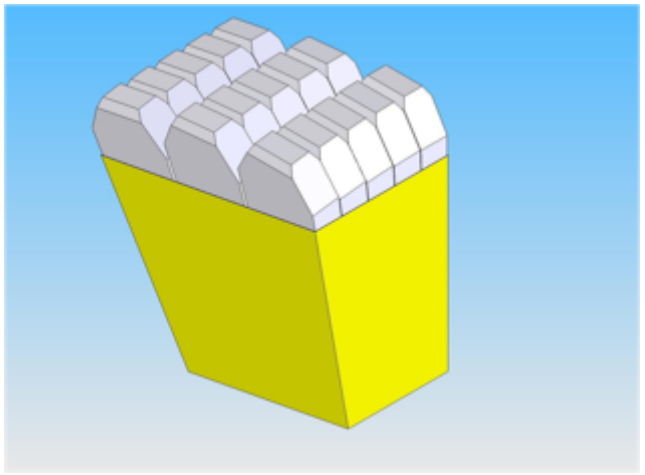
- Backward angles >130º open for access (liquid target/electronics)
- BARREL 40 – 130º → CsI(Tl) + LAAPD
- FORWARD ENDCAP 6- 40º → improved angular and energy resolution, thinner/longer crystals, phoswich?

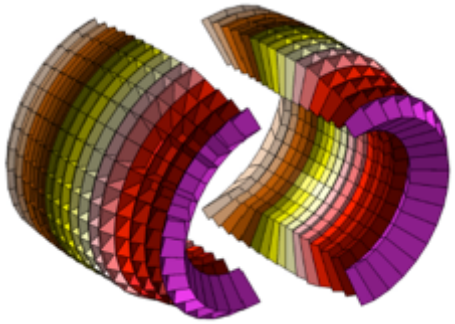
Design/Simulations of barrel

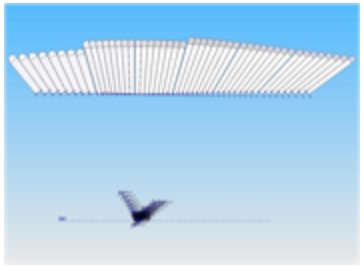
Following Presentation

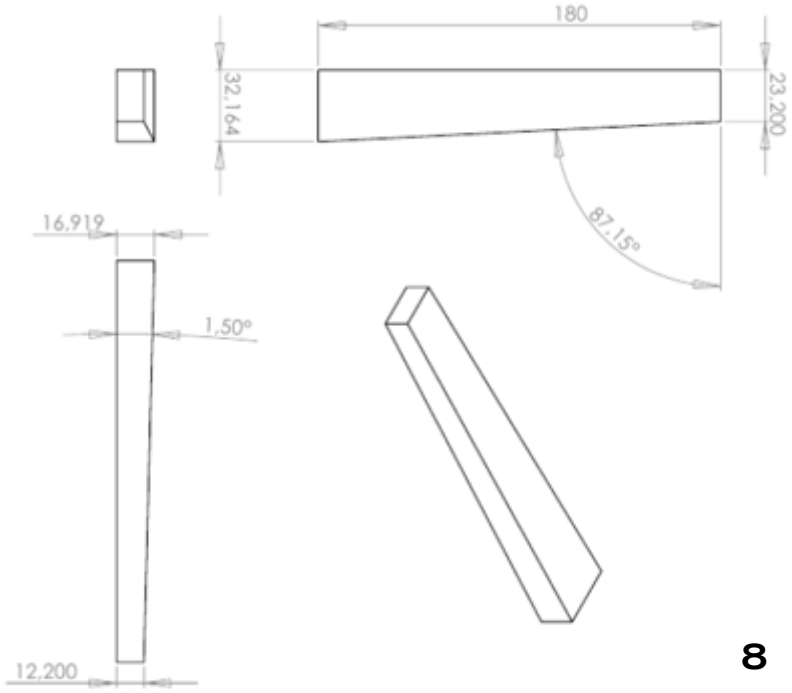
H. Alvarez-Pol (Univ. Santiago de Compostela, Spain)

Design and simulation of a calorimeter/spectrometer for the R3B setup:
the CALIFA BARREL





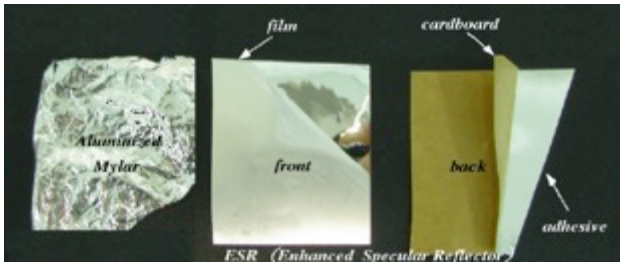




Inner radius	30 cm
Numb. of crystals	1952
Diff. crystal geometries	31
Crystal weight (CsI(Tl))	≈ 2000 kg

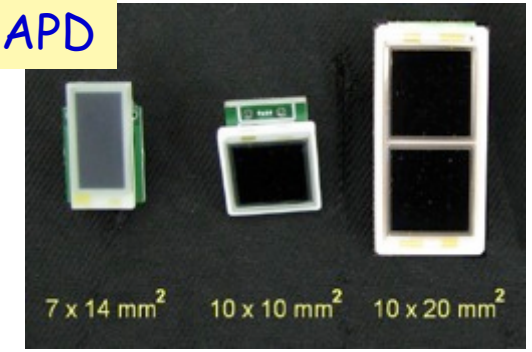
Crystals have been tested extensively

CsI(Tl)



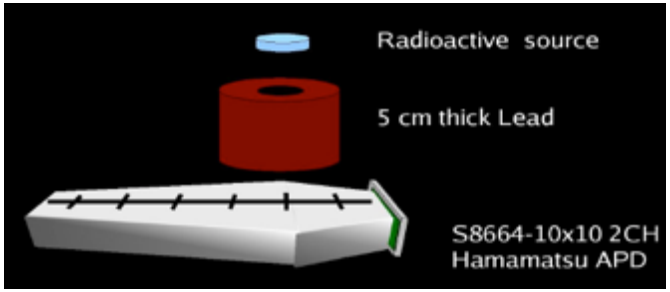
Following Presentation

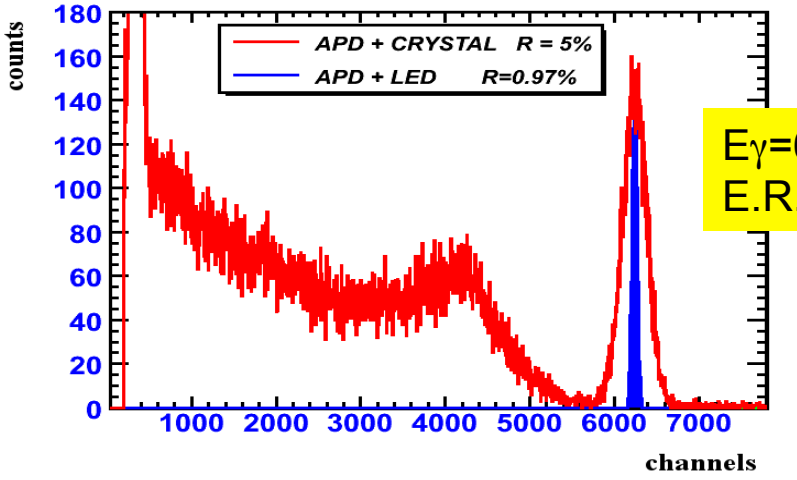
APD



B. Pietras* (GENP-USC, Spain)

The DemoZero for CALIFA BARREL: experimental and simulated results



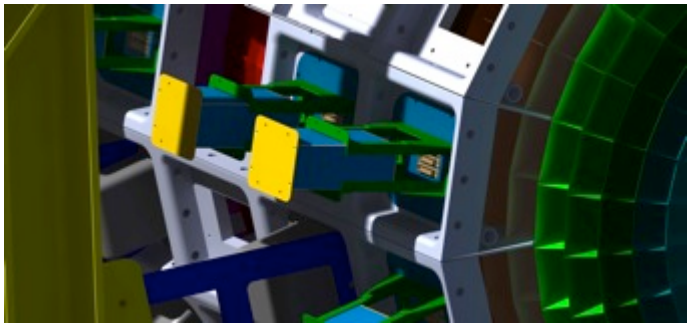


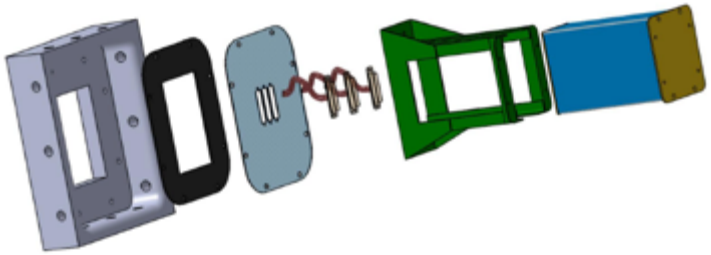
Eγ=662 KeV
E.R. 4.4%

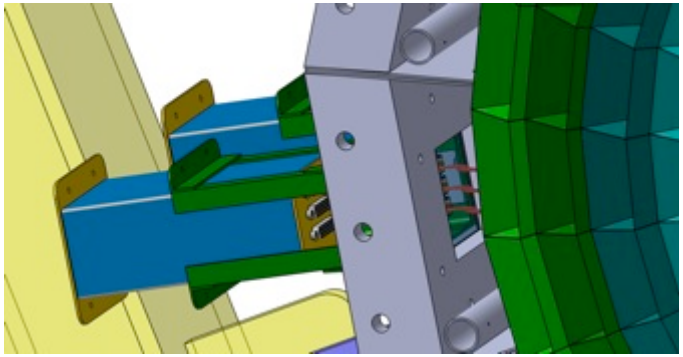
PreAmp solution

Mixed concept with analog bias regulated PA , followed by digital electronics

Talk by: T. Le Bleis * (T.U. Munich)
PID and plastic phoswitch for CALIFA for R3B





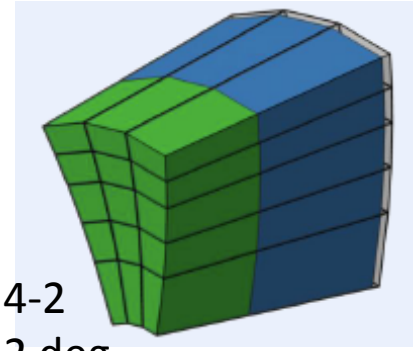


MPRB-16 **16 channel charge sensitive preamplifier with integrated bias voltage generators.**

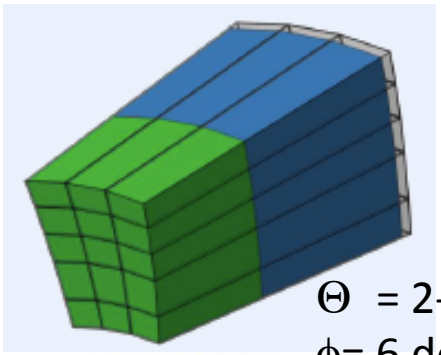
- **Remote controllable via mesytec control bus**
- **Voltages integrated individually for each channel in 100 mV steps, up to 600 V.**
- **Temperature sensor to compensate the APD gain drift with temperature by regulating the bias voltage.**

Forward EndCap Possible solution a ΔE-E telescope?

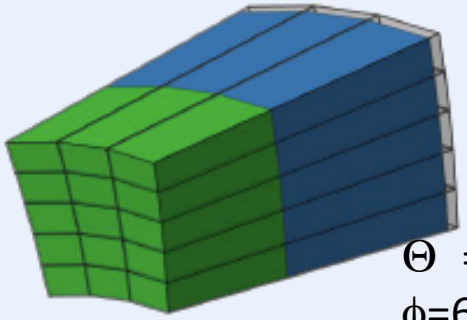
CEPA



Θ = 4-2
ϕ = 12 deg

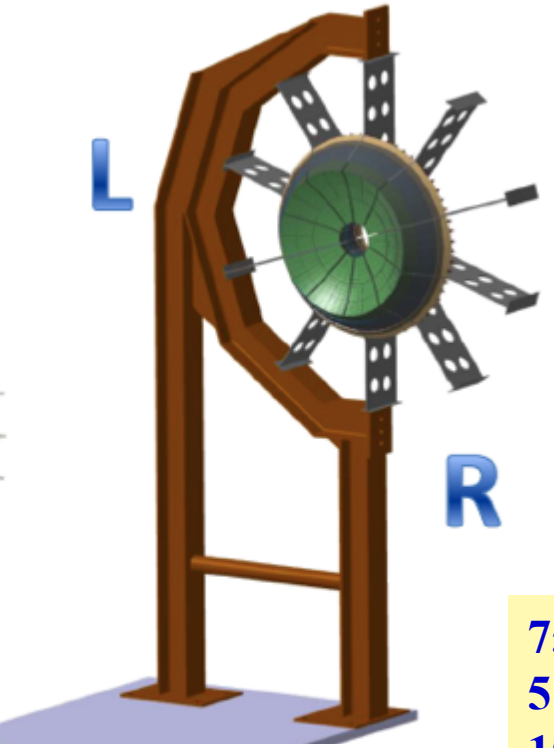


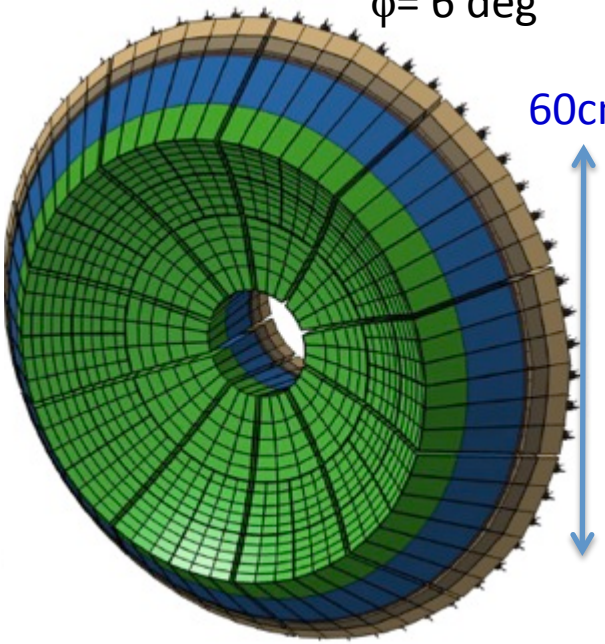
Θ = 2- 1.5
ϕ= 6 deg

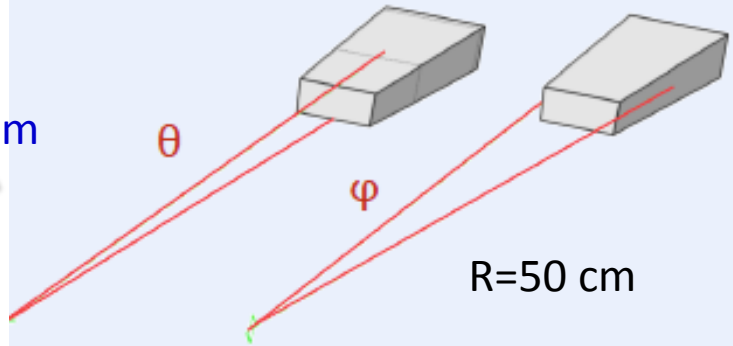


Θ = 1.5
ϕ=6 deg

L1A Matrix → Final arrangement: 750 Crystals

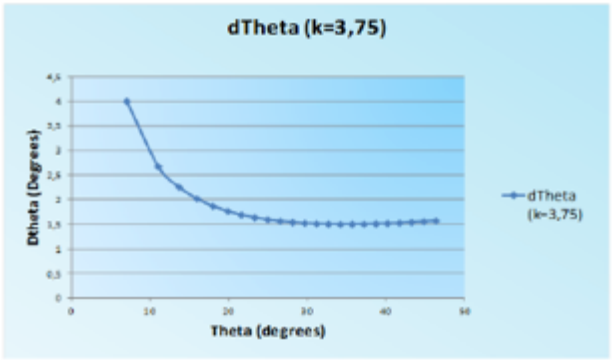






R=50 cm

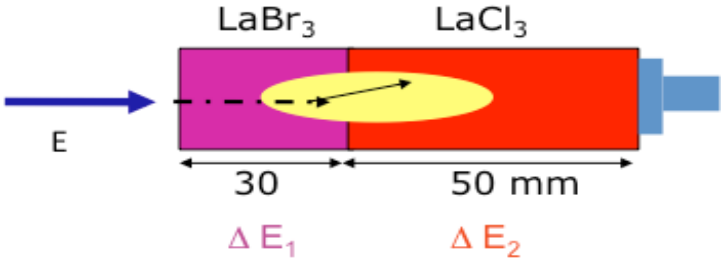
Polar (θ) & Azimuthal (φ) angles

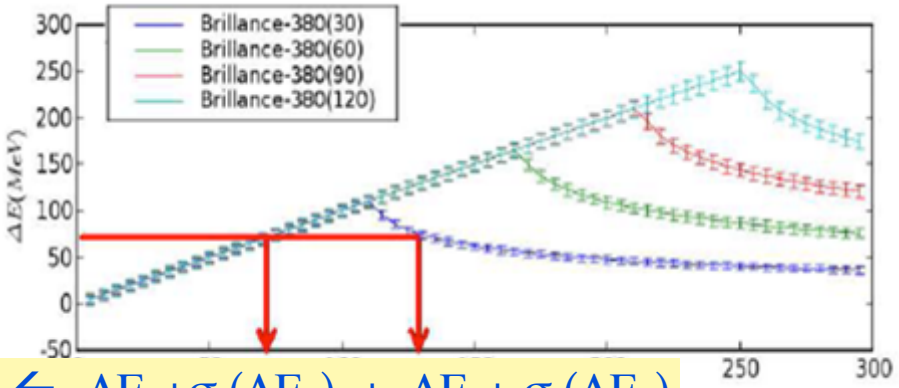


750 crystals:
5 alveoli of 15 crystals
10 branches of 75 crystals, in 15 rings

Jorge Sanchez Rosado
IEM-CSIC

Forward EndCap crystal solution – Phoswich

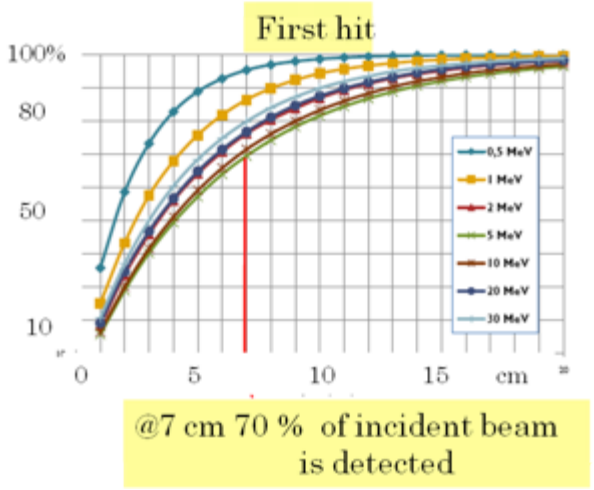




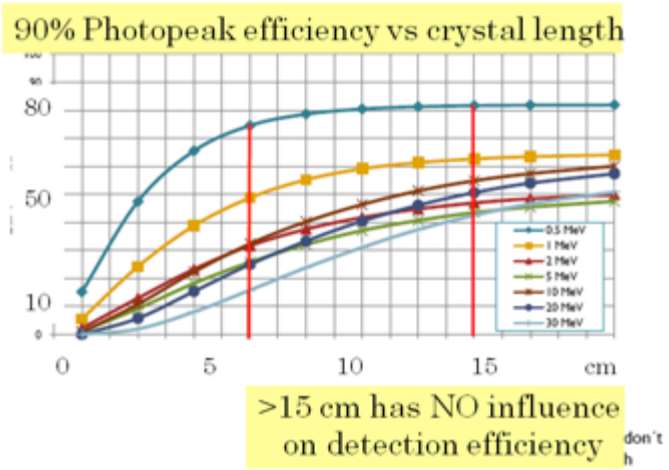
$E \leftarrow \Delta E_1 + \sigma(\Delta E_1) + \Delta E_2 + \sigma(\Delta E_2)$

Question to be answered:

- Depth of first interaction
- Depth @ 90% incident energy absorbed
- How many neighbouring crystals are being hit?



@7 cm 70 % of incident beam is detected



>15 cm has NO influence on detection efficiency

Protons:

Using two ΔE-detectors one can determine the full proton energy with a resolution of <5%.

Gammas:

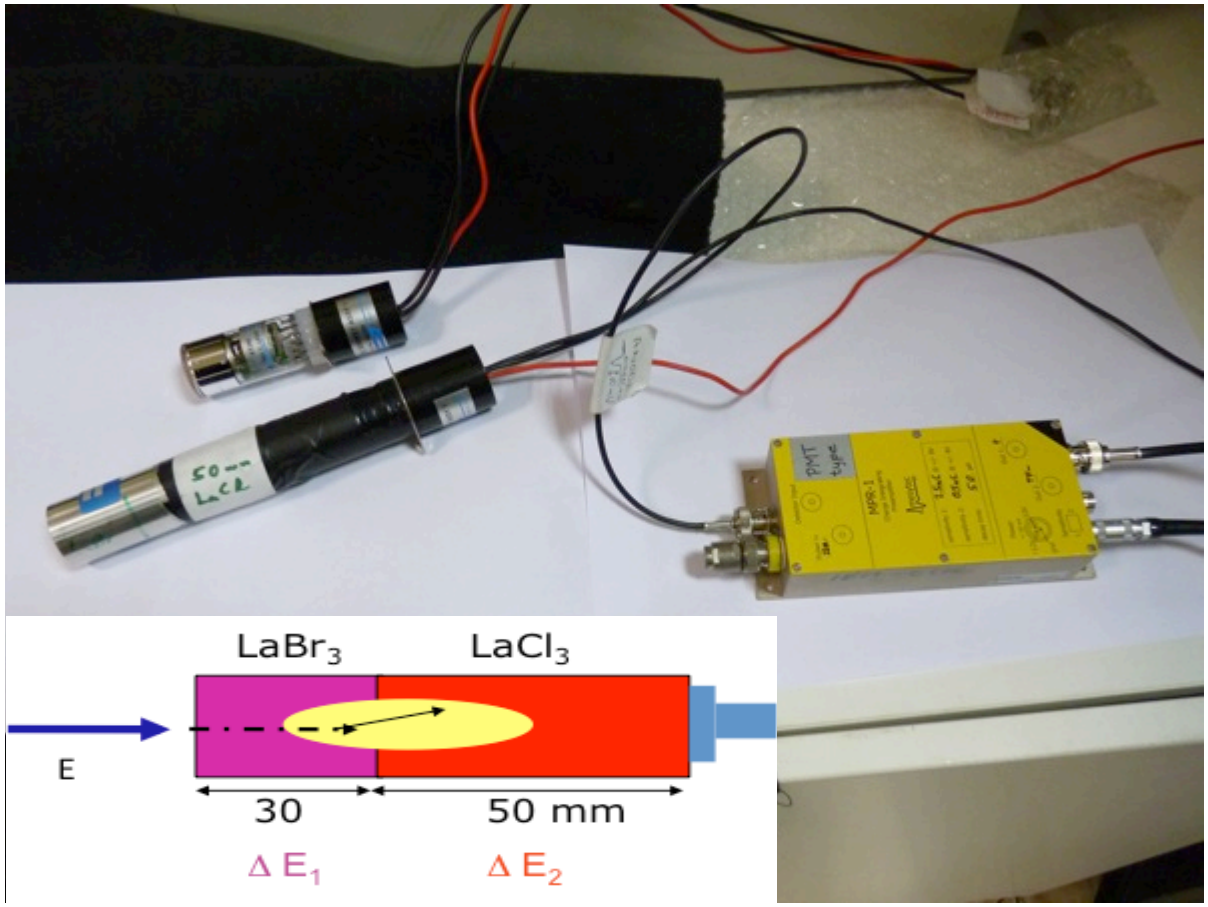
Second detector placed to solve the ambiguity on the signal

Laboratory tests with 1:st prototype

Phoswich: SaintGobain
$LaBr_3(Ce)+LaCl_3(Ce)$
Φ20mm x (30+50)mm^2

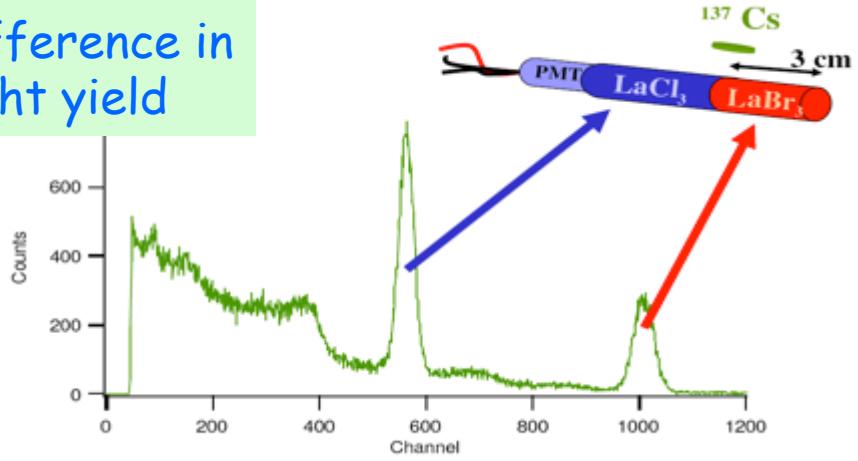
PM-tube: Hamamatsu
R5380 6 dynodes
300-650 nm

PA: Mesytec MPR1-PMT



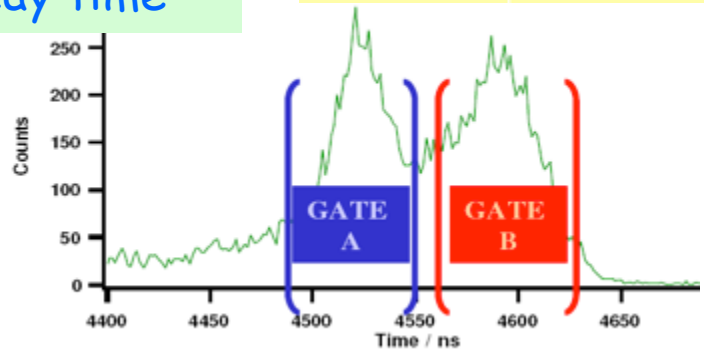
Phoswich: 1st results → it works

Difference in Light yield

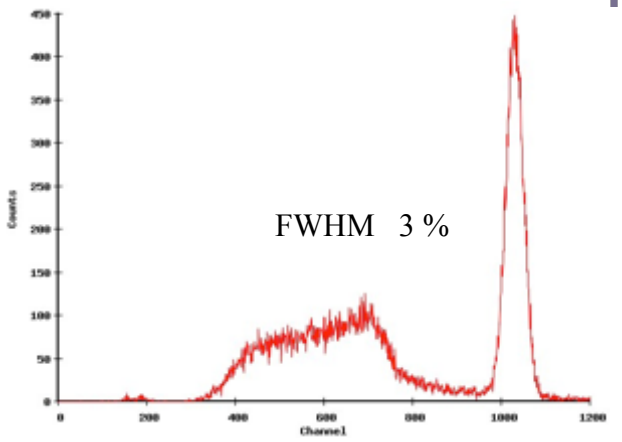


Light yield (photons/keV γ)		Decay time (ns)
63	$LaBr_3$	16
49	$LaCl_3$	28

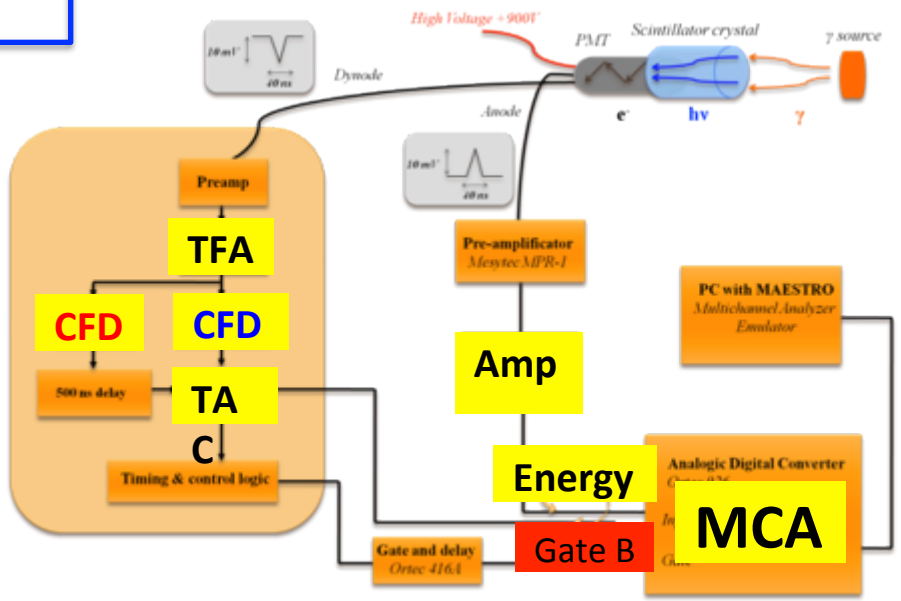
Difference in Decay time



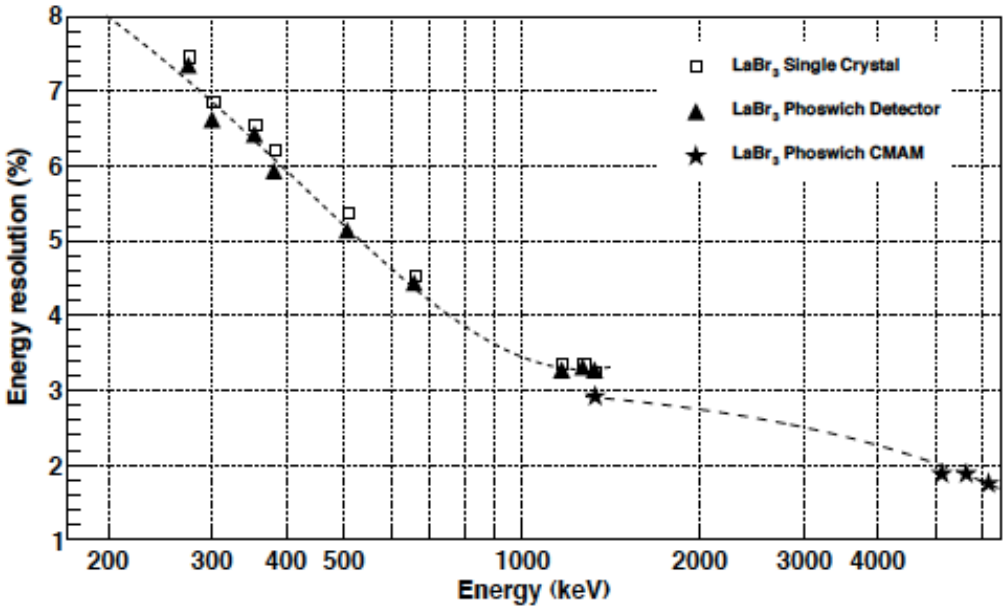
PHOSWICH TEMPORAL SPECTRUM

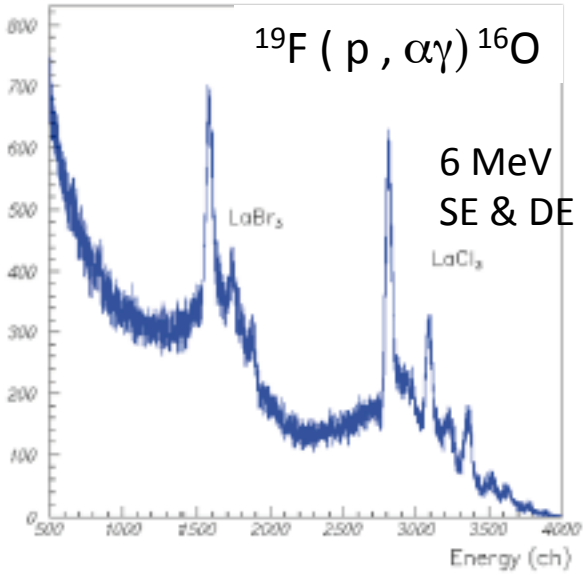


ENERGY SPECTRUM WITH **GATE B**



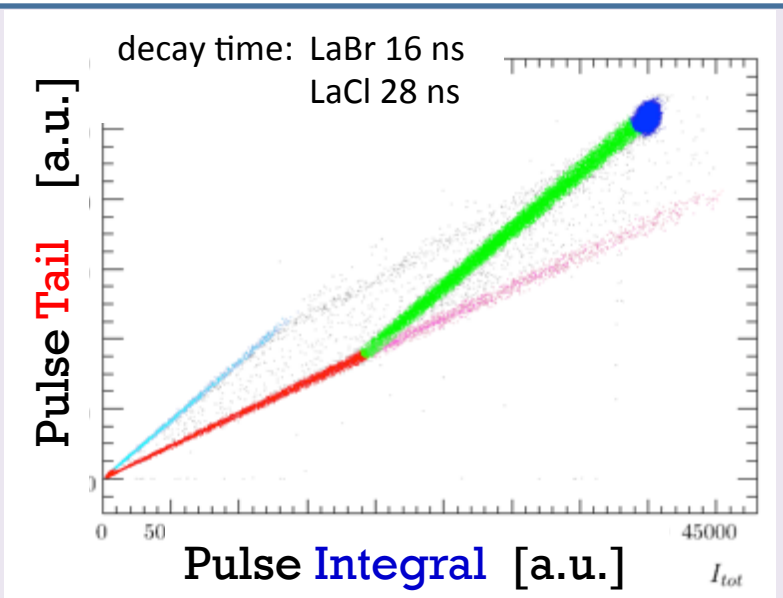
Phoswich vs single crystal

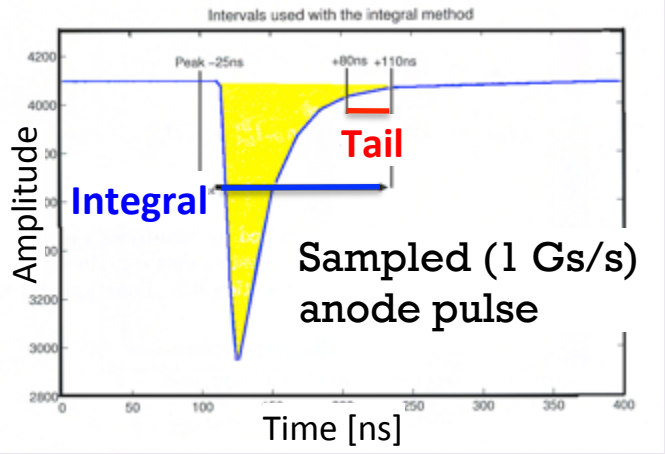




The resolution for the LaBr3(Ce) response in the phoswich compared to an individual crystal. As seen the phoswich conguration does not deteriorate the resolution. The high energy points where taken shooting 1 MeV p on Teflon.

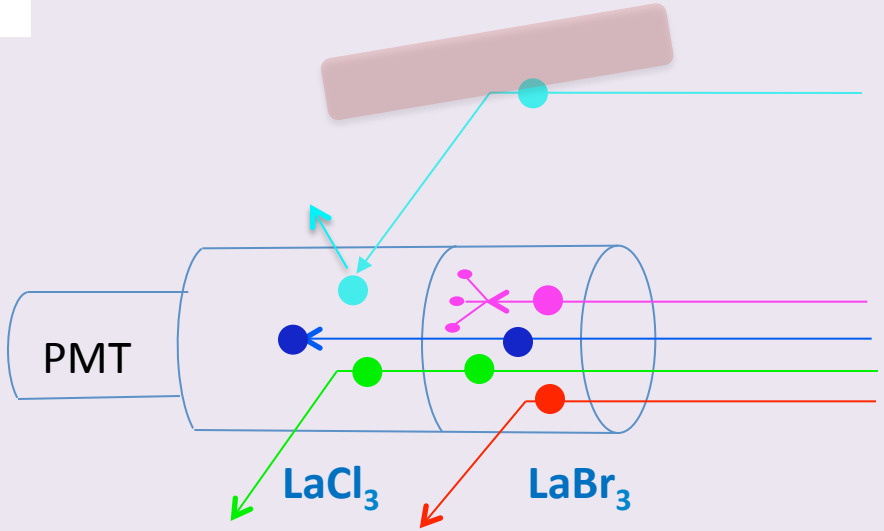
Phoswich detector response to 150 & 180 MeV protons @ The Swedberg Lab. Uppsala





PMT + digital readout

- Proton slowed down in the two crystals
- Proton escaping leaving part of energy
- Proton scattered out from LaBr
- Proton scattering around in 1st crystal
- Proton entered from the side to 2nd crystal
- Pile up & noise



Digital: Anode → Sampling ADC 1 Gs/s MATACQ32 from M2J Saclay → off-line PSA
Analog: Dynode → Mesytec MPR1-PMT → Mesytec STM-16 → Caen V785 ADC

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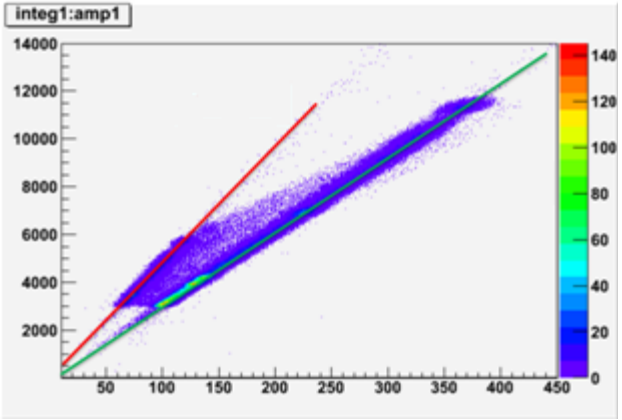
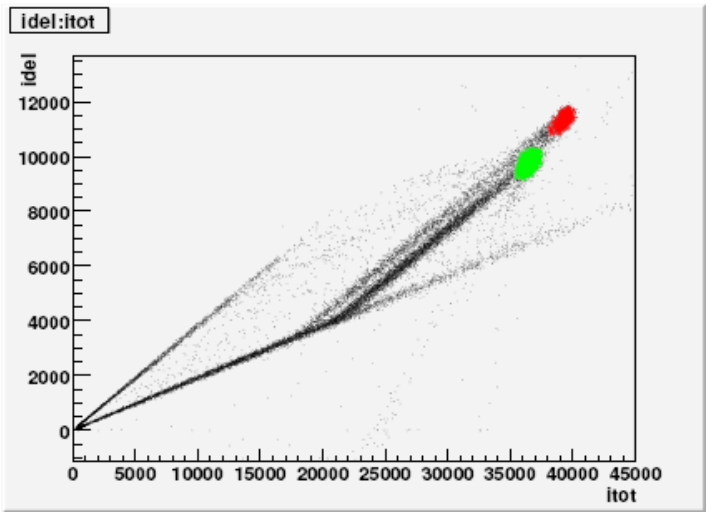
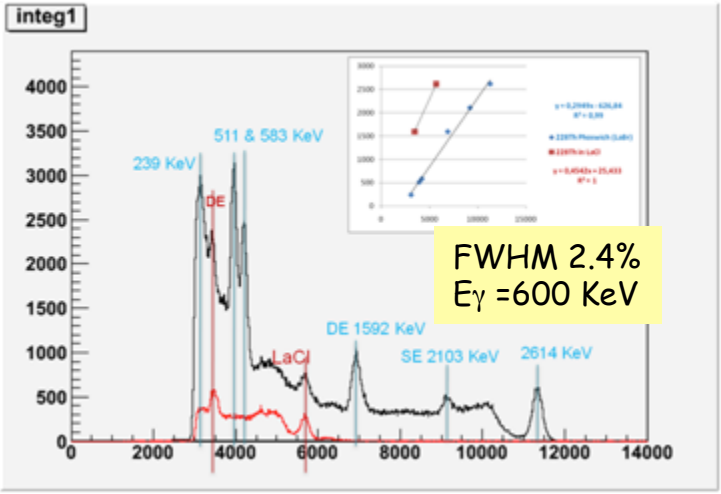
Phoswich response to gammas and protons
Huge dynamic range 200 KeV γ → 200 MeV p
the same digital electronic settings and PM voltage

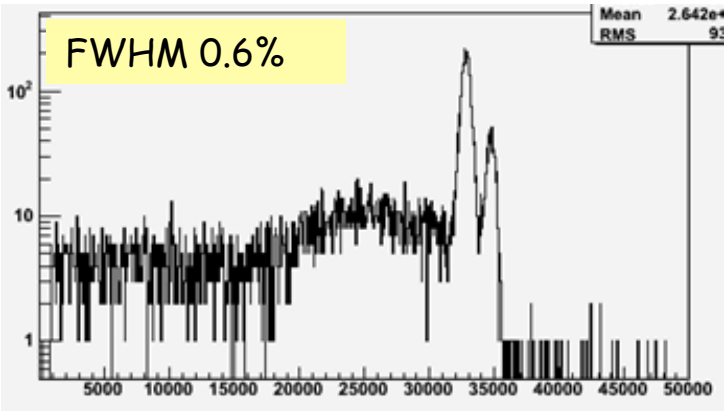


228Th gamma source
Eγ = 200 -2600 KeV





150 + 180 MeV Protons



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Simulation of obtained data

GEANT4 simulartion of the Experiment at TSL

- Proton energy: 180 MeV before leaving the beam-pipe, after the Al cylinder with hole → ≈150 & 180 MeV
- Detector $LaBr_3(Ce) + LaCl_3(Ce)$ cylinder: 2cm x (3 + 5) cm^2
- Physics list:

  Low Energy EM processes (Livermore) for gamma-rays, electrons and positrons. Bertini Intranuclear Cascade for hadrons.

Geant 4 simulations by: E. Nacher

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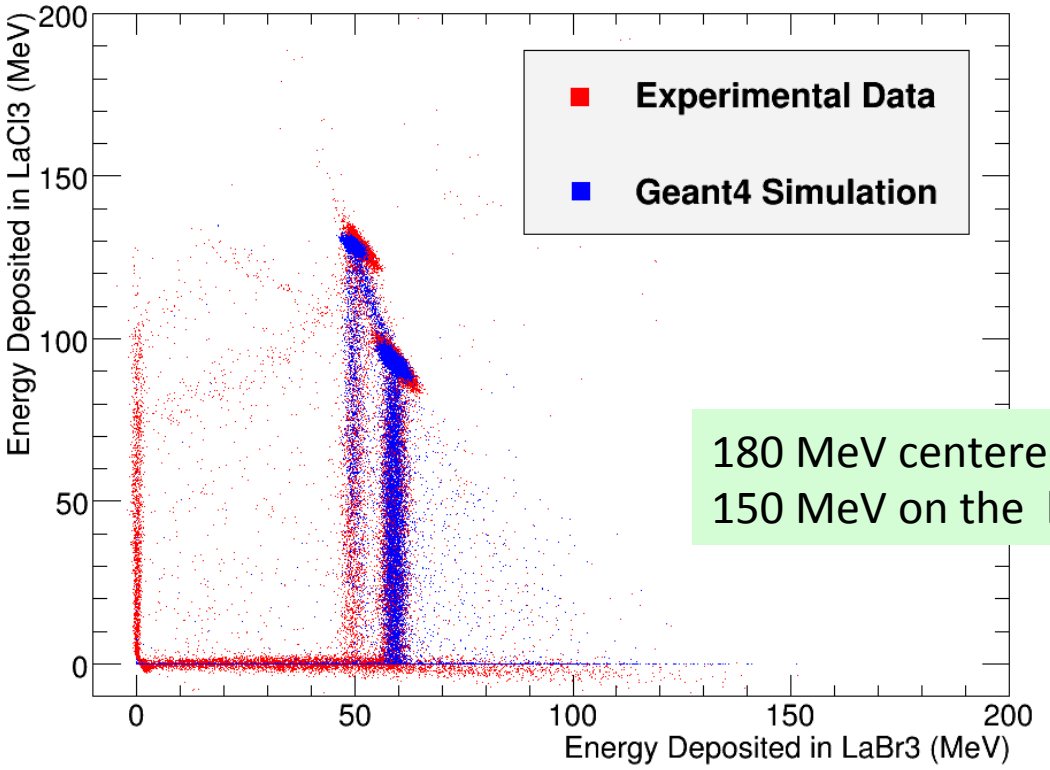
Results

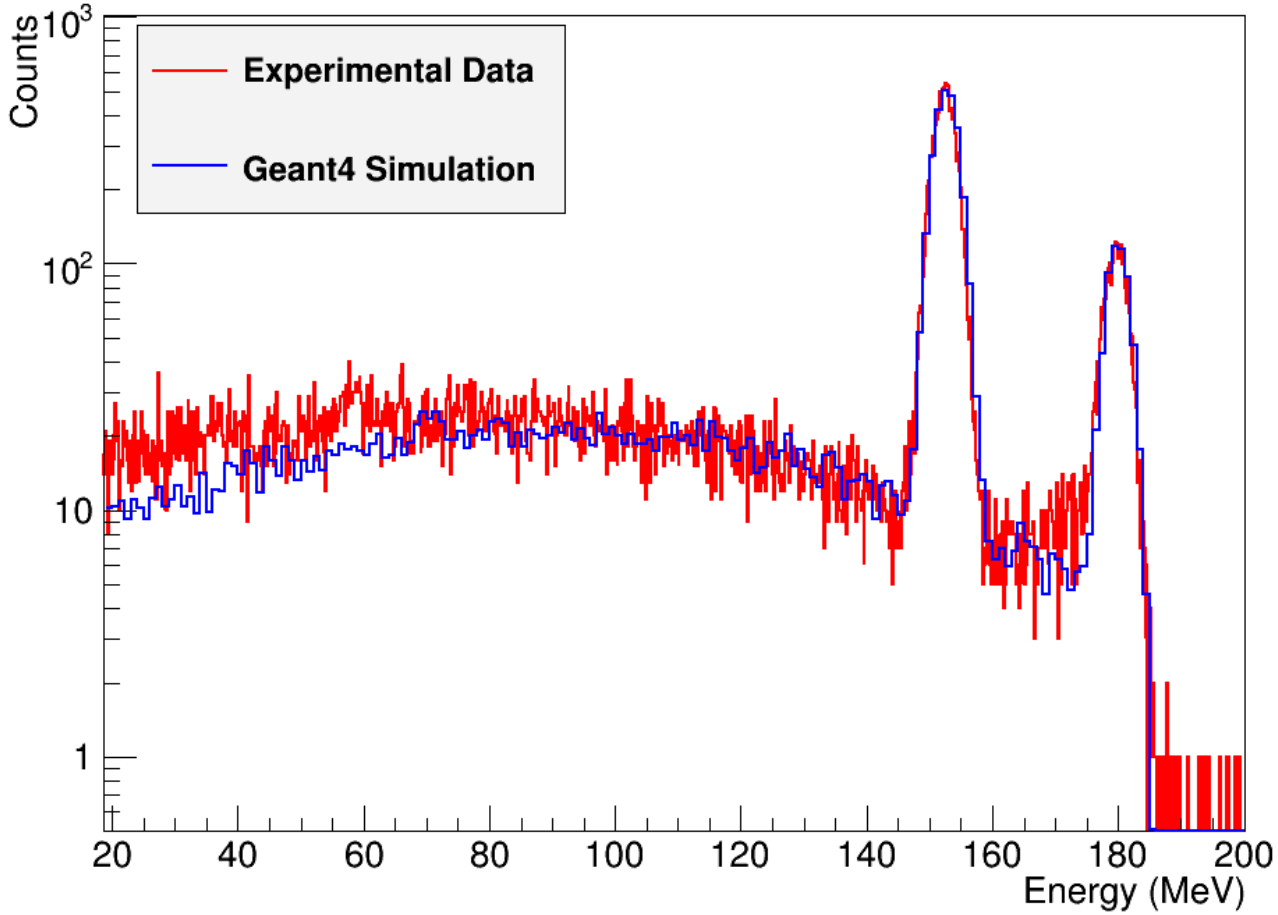
- Energy deposited in $LaCl_3$ vs Energy deposited in $LaBr_3$.
- Data from off-line Pulse Shape Analysis.
- Experimental **data** overlayed with Geant4 **simulation**.

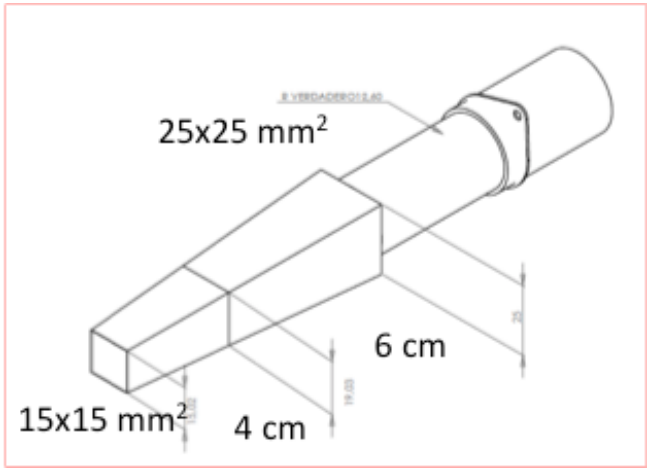


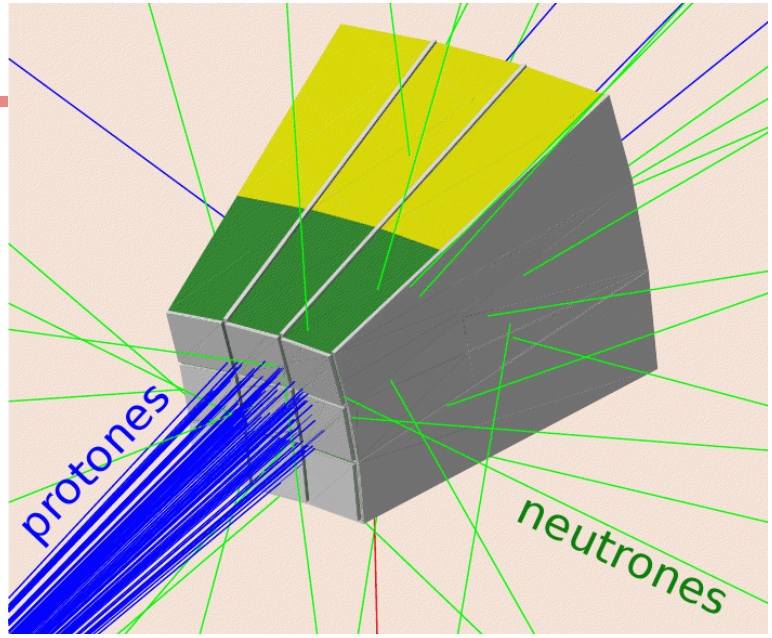
180 MeV centered
150 MeV on the boarder → tail

150 & 180 MeV protons

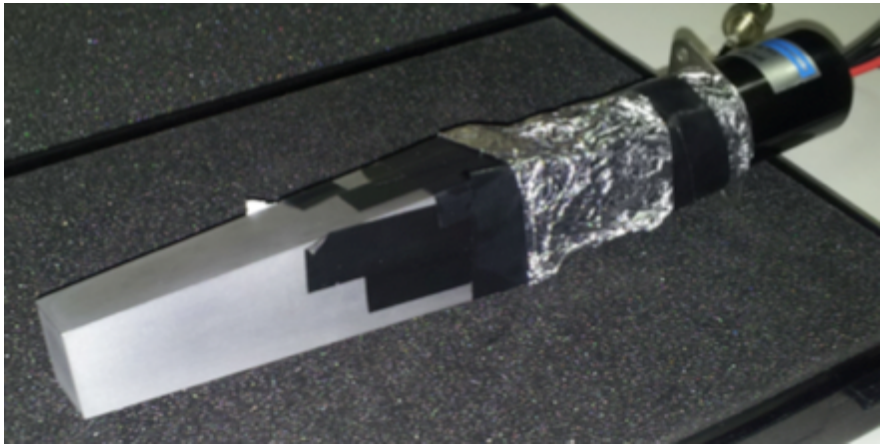
- Energy spectrum adding up the total energy deposited in both crystals Experiment in RED, Geant4 in BLUE



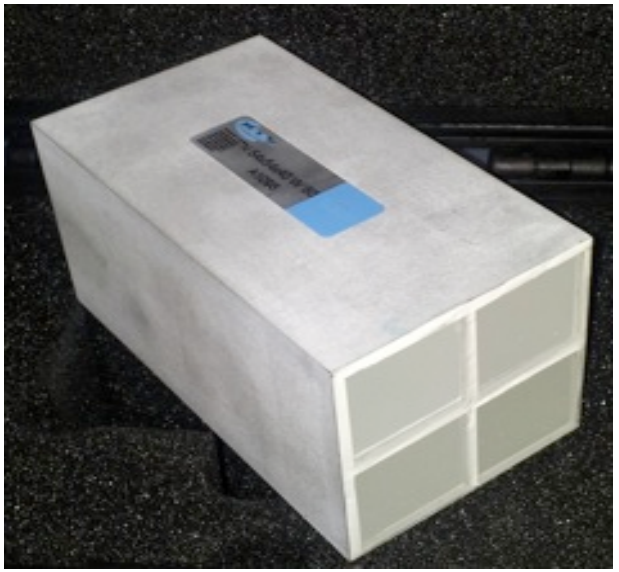




Simulations: Design of 2nd Prototype



Arrived
X-mas 2011

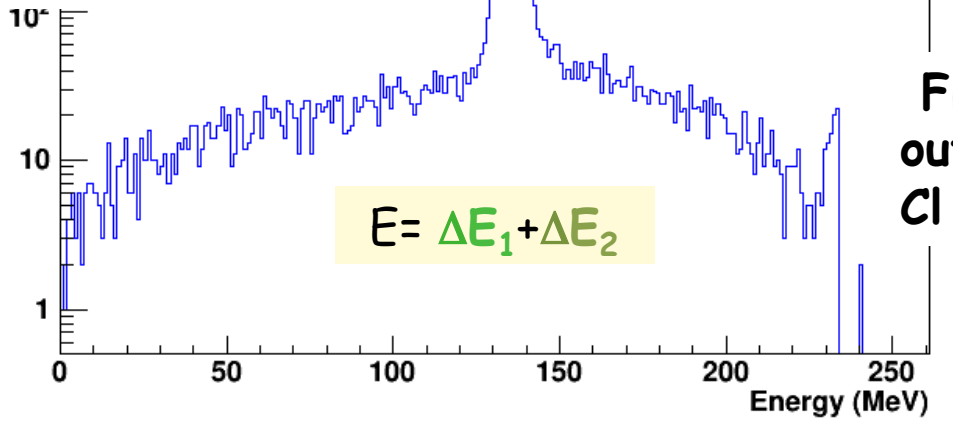


Protons in prototype "CEPA"

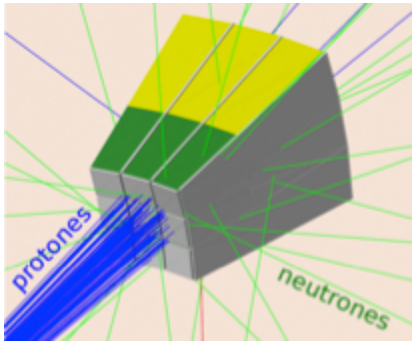
- Energy spectrum for E=240 MeV protons as $\Sigma\,(\Delta E_1 + \Delta E_2)$

Lower E tail: Energy loss due to neutral production at the end (LaCl)

Higher E tail: Energy loss due to neutral production at the begining (LaBr)



Final peak: Knock-out of 1 proton in Br, Cl or La 7KeV<E

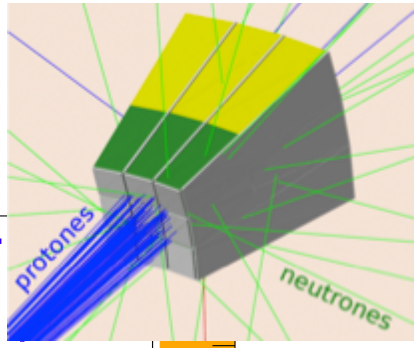


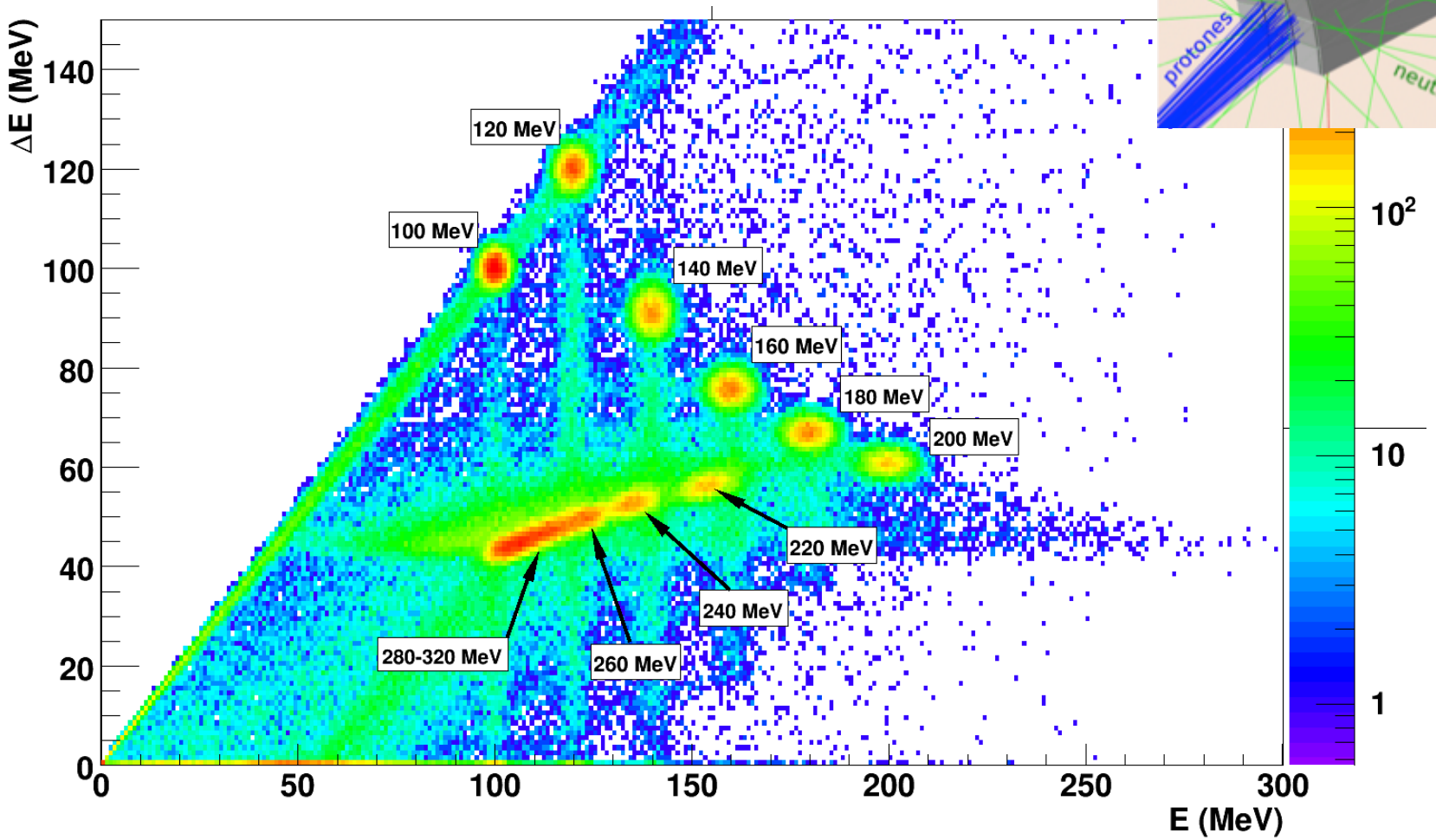
GEANT4 simulations

- **TEFLON 1 mm between crystals and at the entrance window**
- **Hadronic processes included.**
- **Energy resolution included (experimental).**

Protons in CEPA

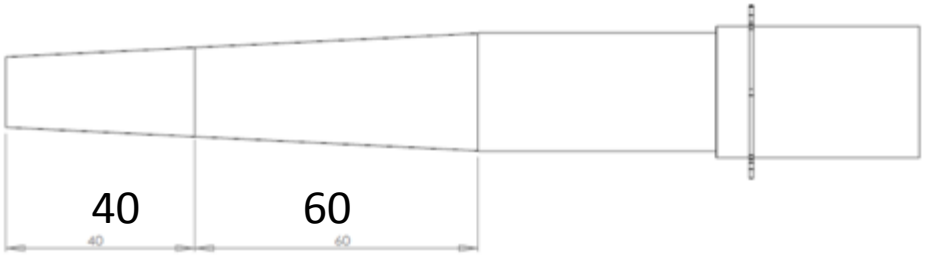
$\Delta E\text{-}E_{tot}$: 100 → 320 MeV in steps of 20 MeV

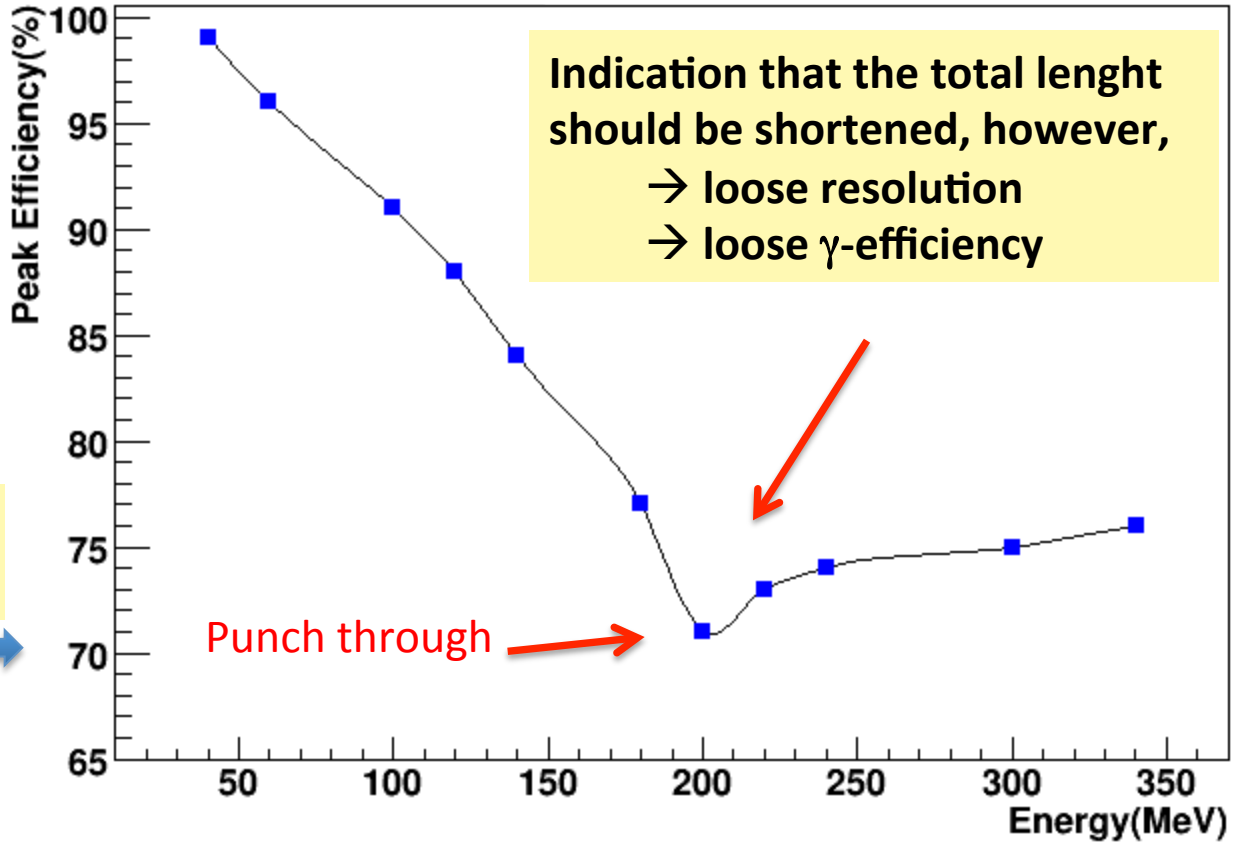




Protons in CEPA

Proton peak efficiency





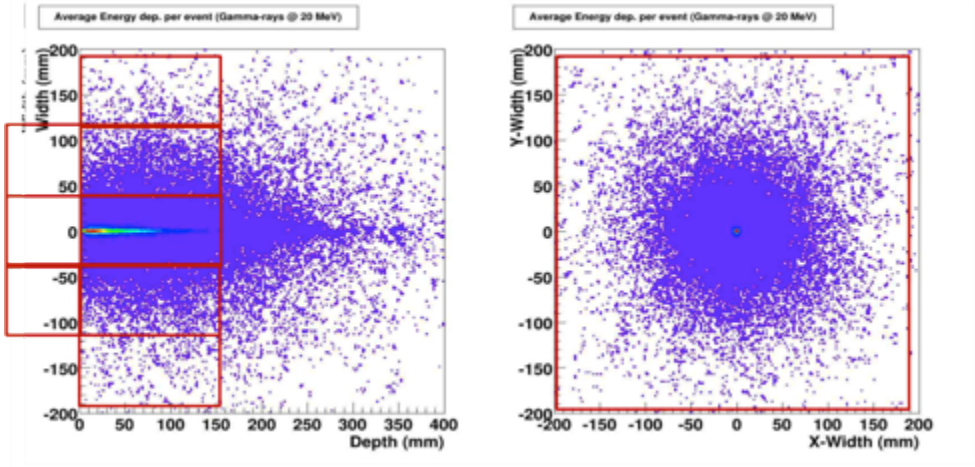
Indication that the total lenght should be shortened, however,
→ loose resolution
→ loose γ-efficiency

Note the scale

Punch through

Detector considerations

Calorimetry: Geometry to absorb Gamma-rays

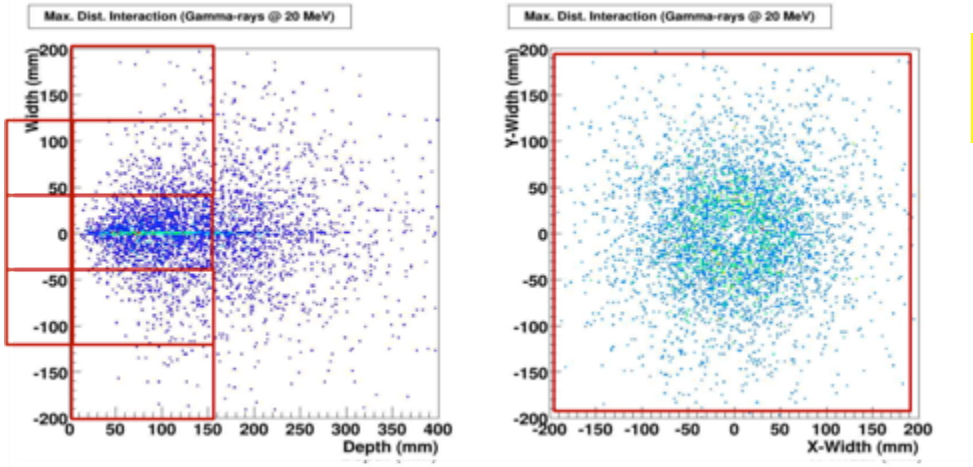


Gamma radiation average energy deposit per event inside an infinite volume of LaBr detector

Considering an infinite volume of $LaBr_3$ 87% of the gamma energy at 20 MeV is deposited within a rectangular prism of 15 cm length 10x10 mm^2 entrance area

→ 91 % efficiency with full add-back from "neigbouring" rectangles

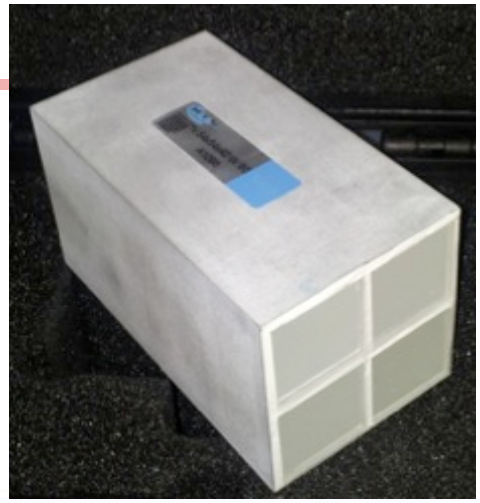
Spectroscopy: Optimize "Photo-peak" efficiency

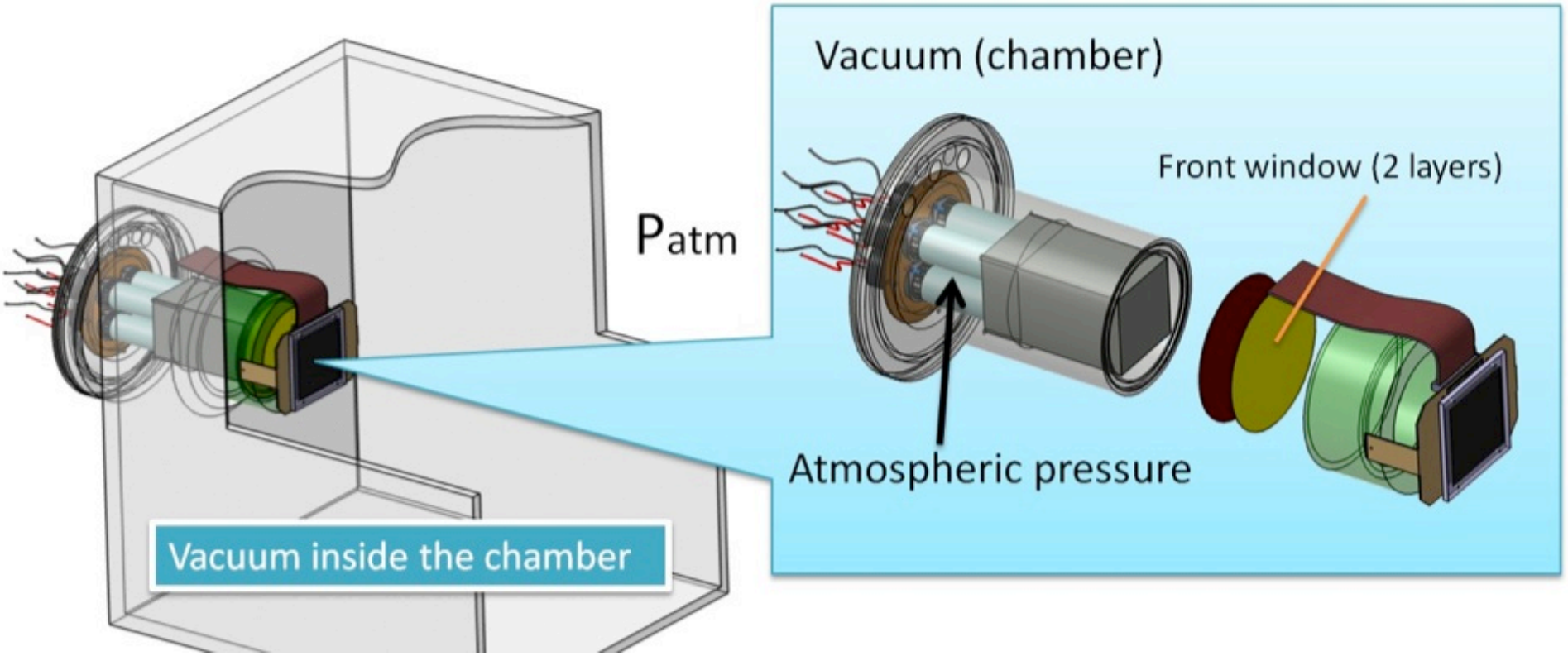


Maximum distance between interactions - absorbing one incident gamma inside a crystal 10x10x150mm^3

Photopeak efficiency		full add-back
@ 10 MeV	36 % →	74 %
@ 20 MeV	16 % →	66 %
@ 30 MeV	7 % →	56 %

CEPA 1.0
to be tested 2012





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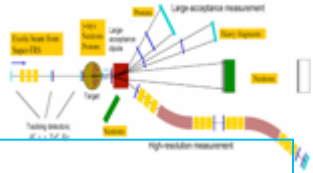
Summary

- **R^3B - Reactions with relativistic radioactive beams yield unique possibilities for studies of nuclear systems at the extremes**

- **CALIFA is a versatile γ / p detector for the R3B setup at FAIR**
  - CALIFA Barrel TDR was handed in dec. 2011
    (more in following talks)
  - **CEPA: Califa End Cap Array on going R&D**
    - **Mechanical and geometrical design exist**
    - **Phoswich solution is the most probable**
      - **LaBr+LaCl phoswich has been tested and simulated as a possible solution**

CALIFA



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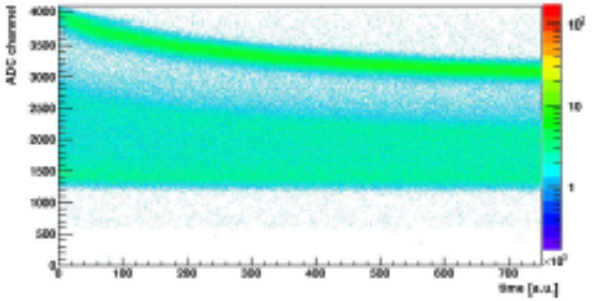
Thank you for the attention!

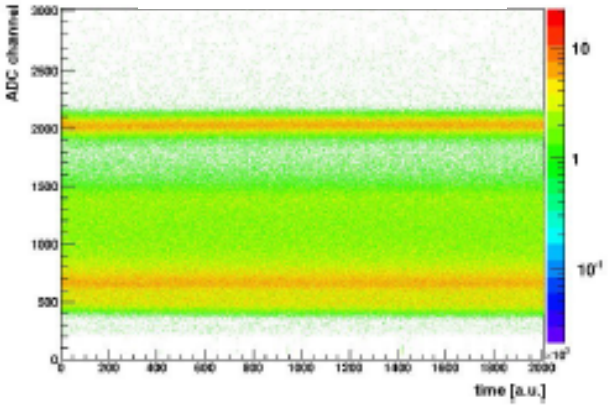
LAPD Voltage stabilization to ambient temp

Spectrum of a ^{137}Cs source measured with a CsI(Tl)-crystal and read out by an Hamamatsu S8664-1010 LAAPD.

$$\frac{1}{G}\frac{dG}{dT} = -2.95\frac{\%}{^{o}C} \qquad \frac{1}{G}\frac{dG}{dU} = 2.5\frac{\%}{V}. \qquad \frac{dU}{dT} = 1.18\frac{V}{^{o}C}$$



Gain gradient due to continuous heating
of the LAAPD from 11 to 23 ^{o}C



Temperature regulated
in the range of 6 to 24 ^{o}C

Talk by

T. Le Bleis * (T.U. Munich)
PID and plastic phoswitch for CALIFA for R3B