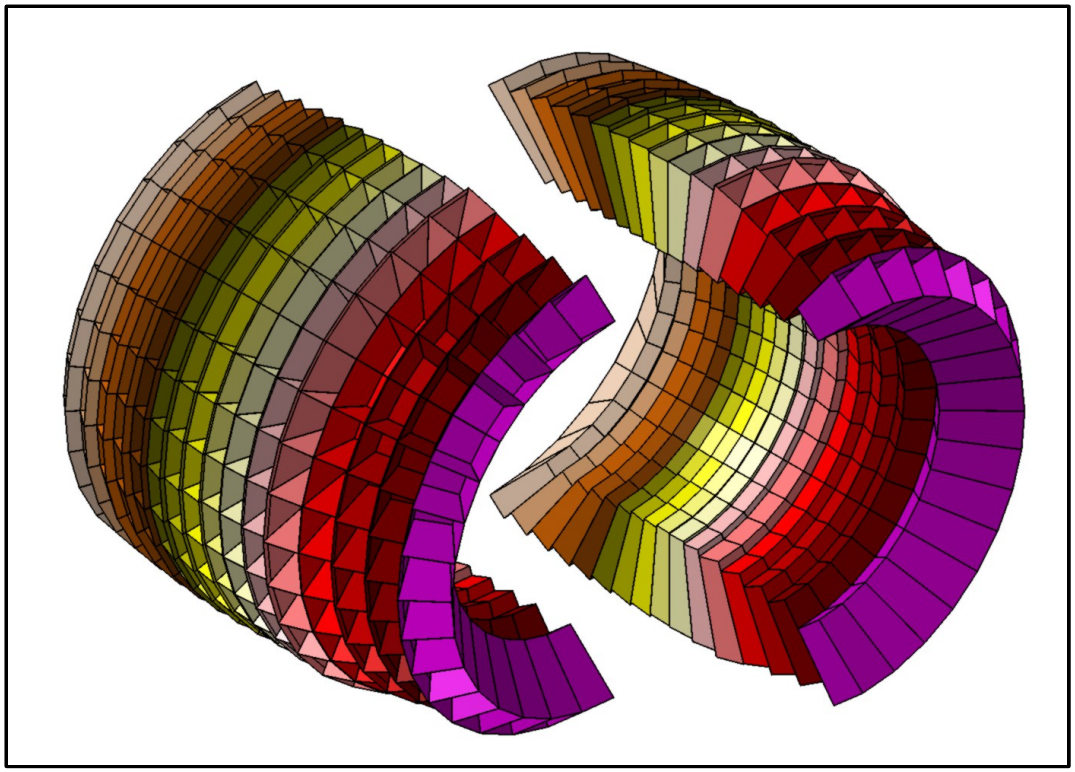
The CALIFA calorimeter in the versatile R^{3}B setup



H. Álvarez Pol
for the R^{3}B Collaboration and the CALIFA WG.

GENP, Dpto. Física de Partículas,
Universidade de Santiago de Compostela

Content index

1. Introduction to the R^3B setup…
   1. … Structure of light nuclei: the S393 experiment.
   2. … SOFIA: fission studies toward a complete fission R^3B setup.
2. The CALIFA detector in R^3B:
   1. Detector concept.
   2. Electronics, tests and mechanics.
   3. Simulation studies.

Summary and outlook.

S393: Light *Neutron-rich Nuclei at and Beyond the Dripline*
Kinematically Complete Measurement using Direct Reactions

Systematic study with isospin assymetry:

- Modification of the mean-field by short and long range correlations (N>>Z)...
- → Evolution of the shell gaps and magic numbers.
- Enhanced monopole interaction acting between proton-neutron spin-orbit partners.

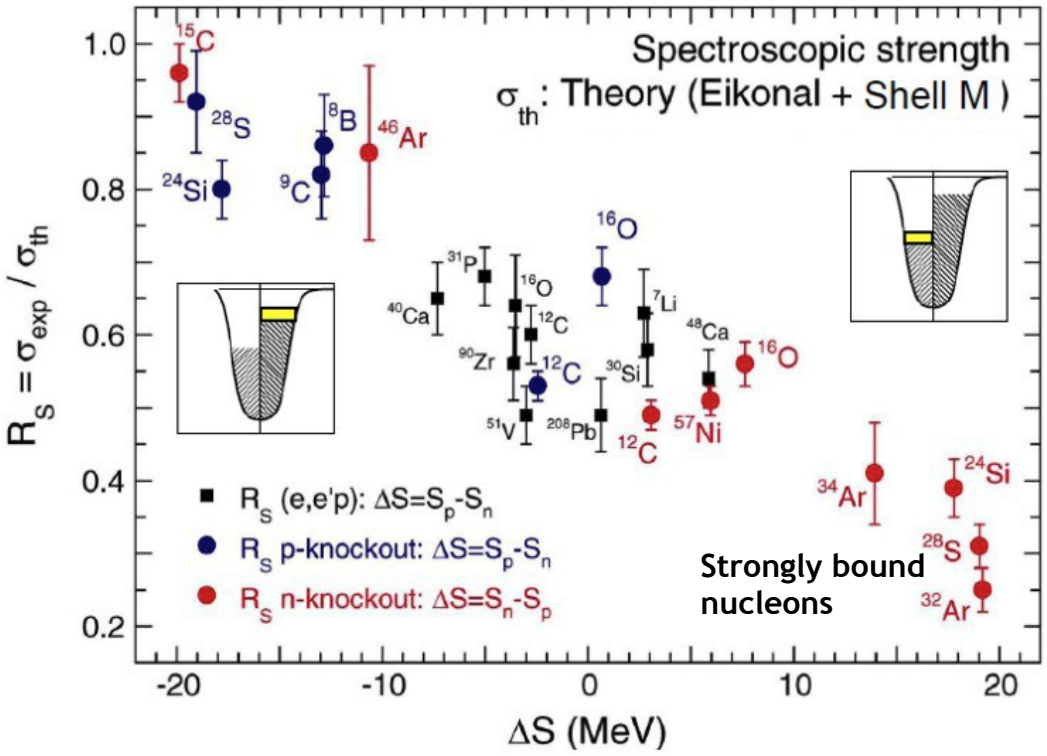
What we ask for (from our data):

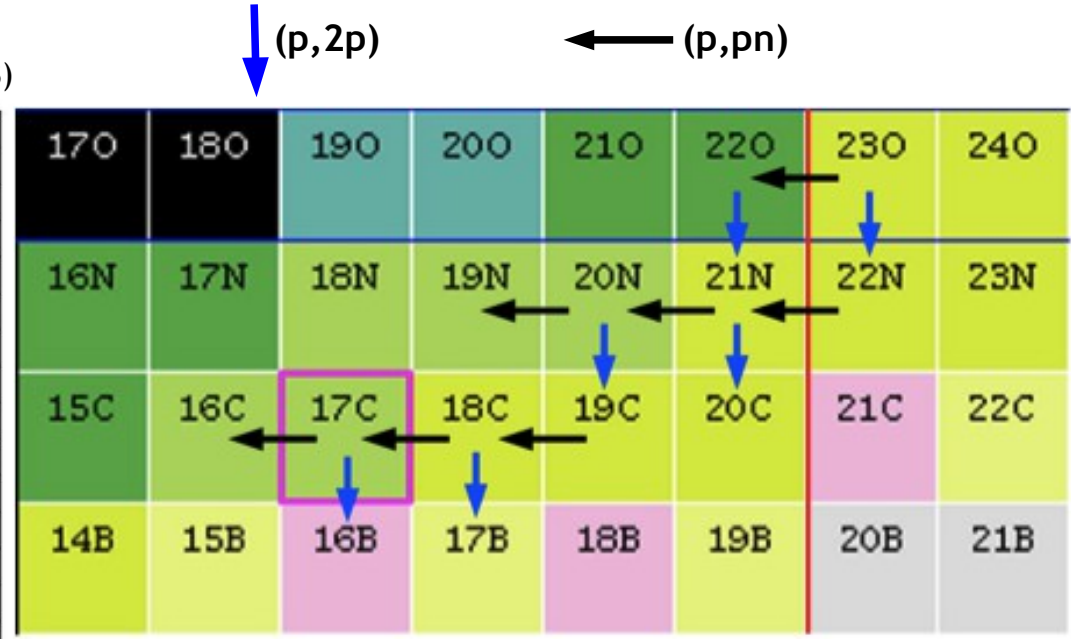
- Hints on the variation of the magic numbers.
- New shell closures at N=14 and N=16.
- Dependence with isospin of the occupancies.

Check the strong depletion of occupancies of deeply-bound neutrons in proton-rich nuclei.

Weakly bound nucleons

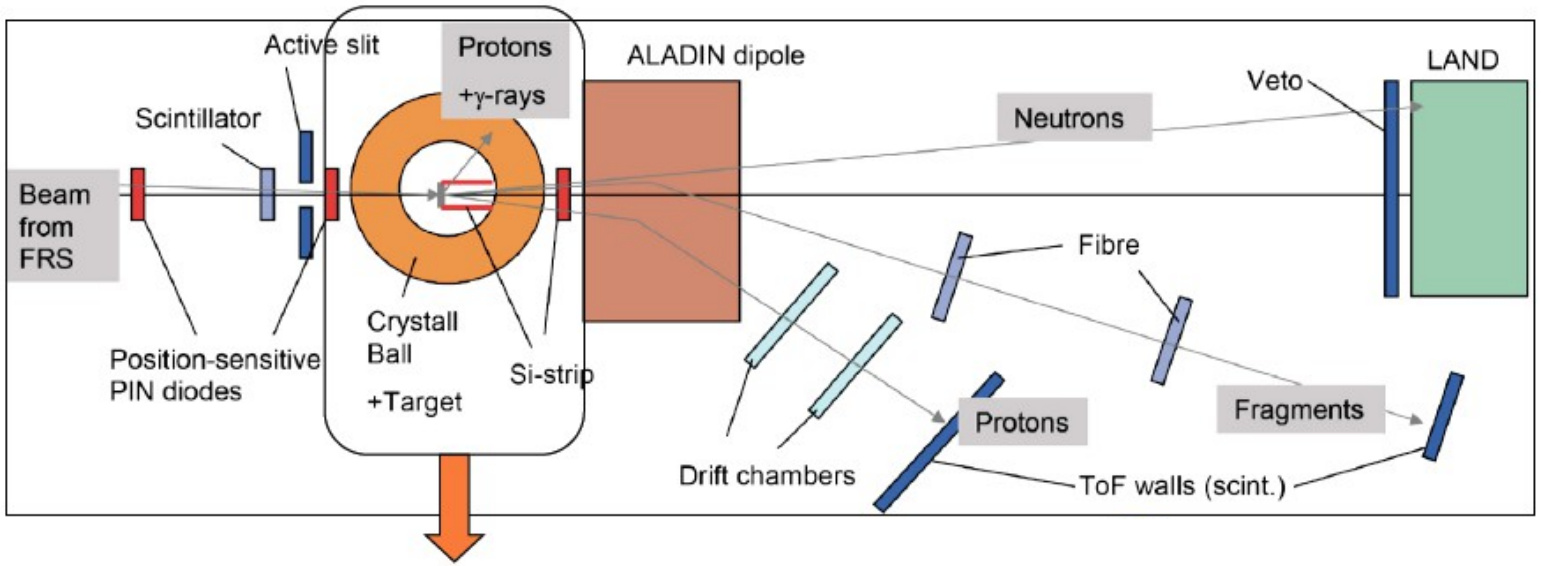
A. Gade, Phys. Rev. C 77 044306 (2008)

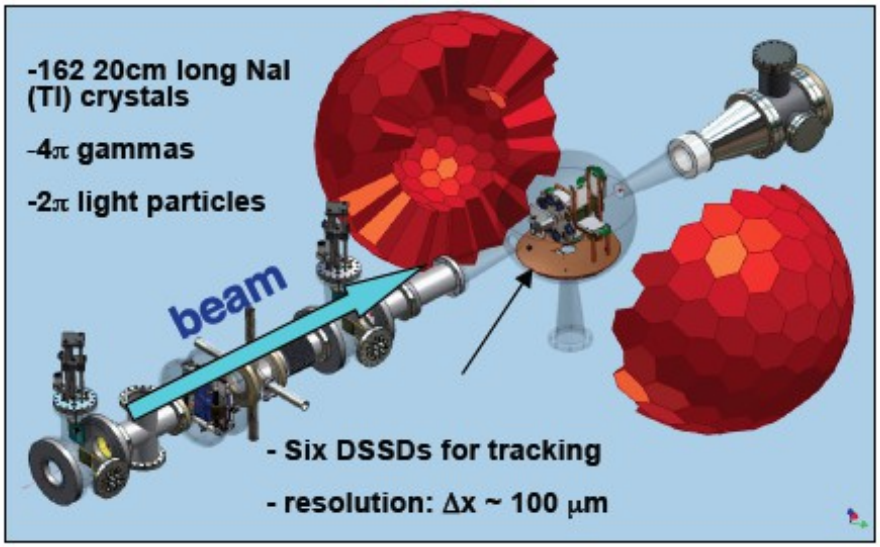


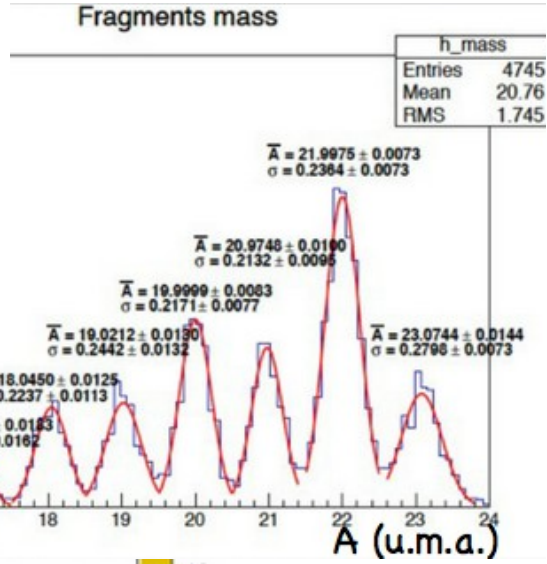


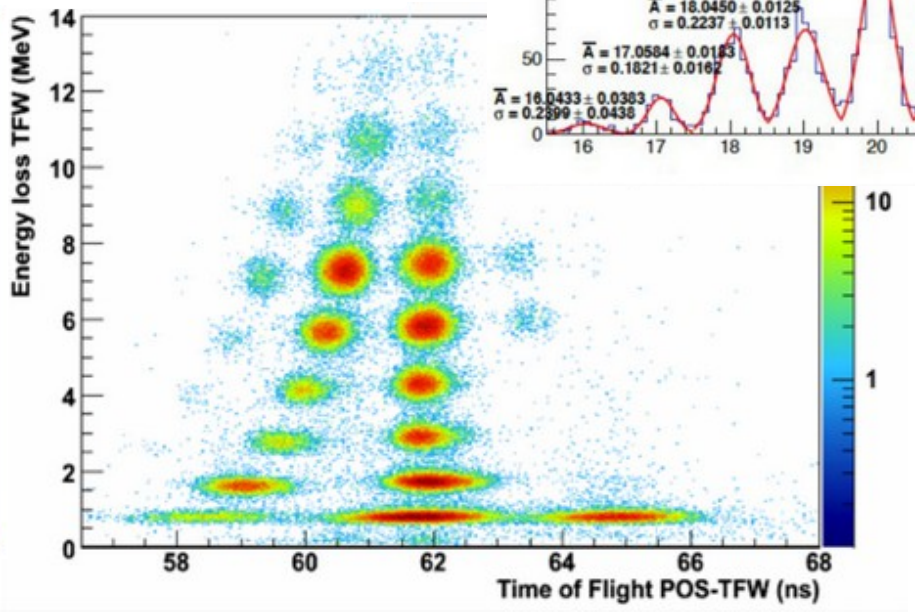
First R3B experiment, performed last August 2010.

S393: Light *Neutron-rich Nuclei at and Beyond the Dripline*
Kinematically Complete Measurement using Direct Reactions







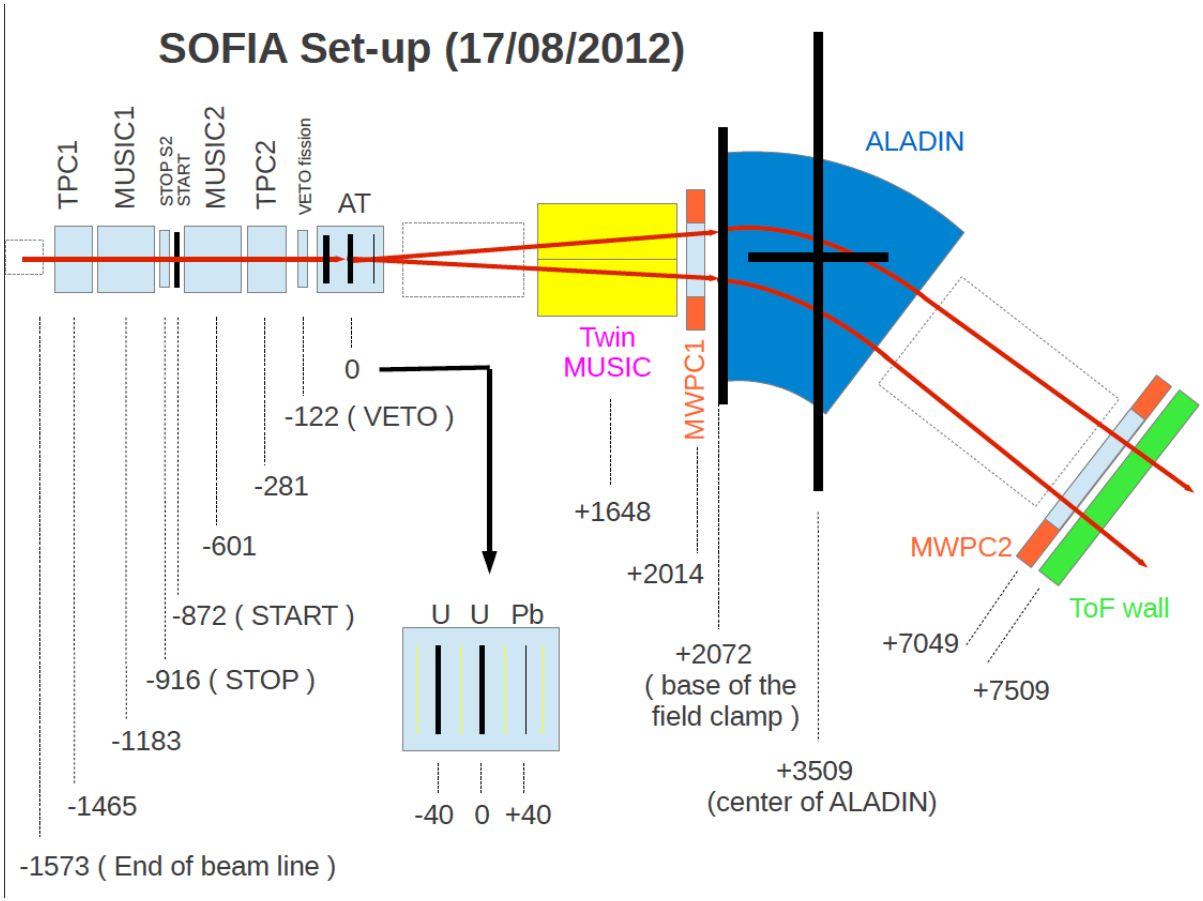


Analysis ongoing: see Paloma Díaz talk last tuesday.

SOFIA fission studies... down of the R3B fission setup

Fission of actinides and preactinides in inverse kinematics at GSI: comprehensive study of fission process at medium and high excitation energy.

- Coulex-induced fission of ^{238}U and lighter short-lived actinides and preactinides (^{236}U, ^{238}Np, ^{218}Th, ^{222}Th, ^{230}Th, ^{202}Rn, …): structure effects at low excitation energy.
- Spallation-fission of ^{208}Pb on H to study fission dynamics at high excitation energy.
- Complete kinematics: Z, A, E_{KIN} counting all fragments and neutrons with high res.



First step to an ambitious campaign!

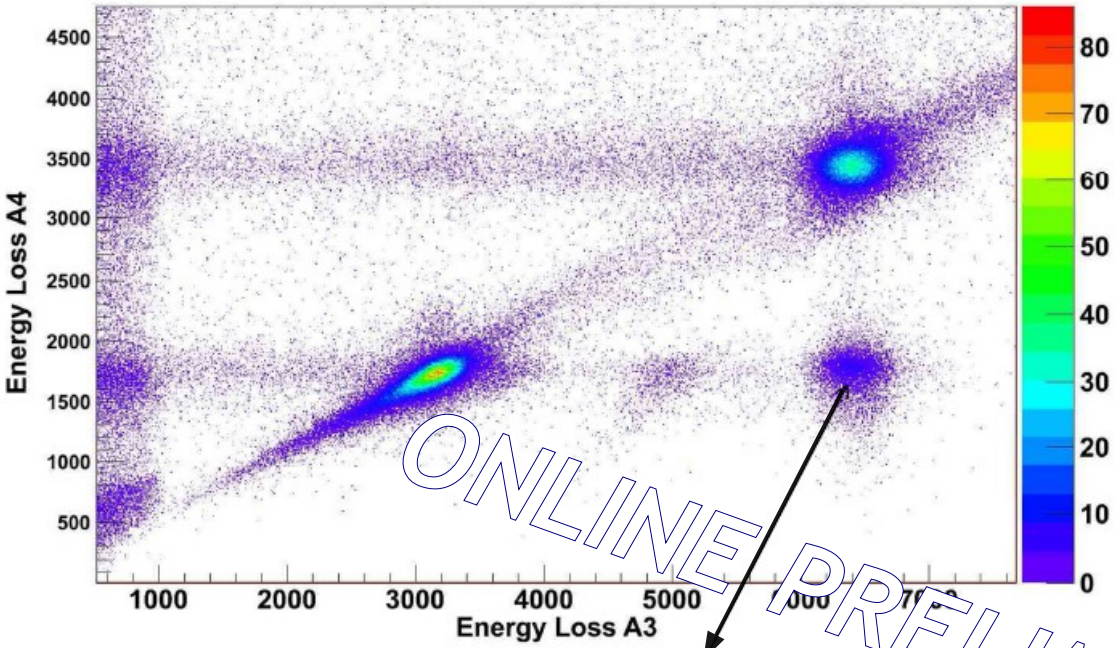
- SOFIA ⟶ **Studies On Fission with GLAD**.
- **CALIFA** will bring information about gamma and LCP emission in fission.

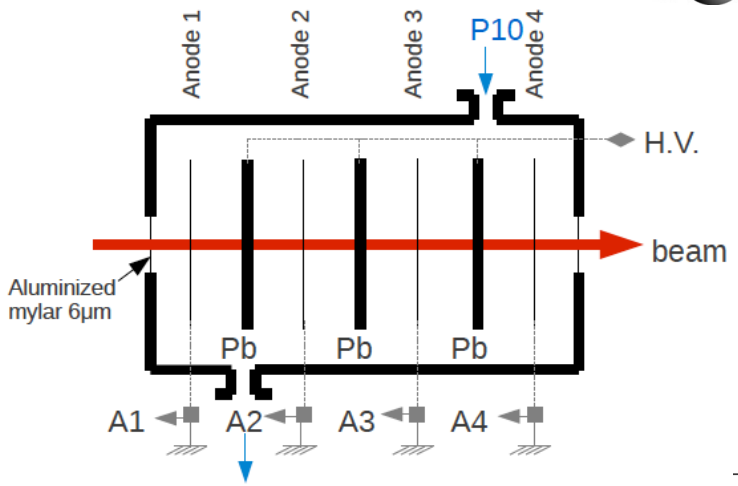
SOFIA collaboration members:

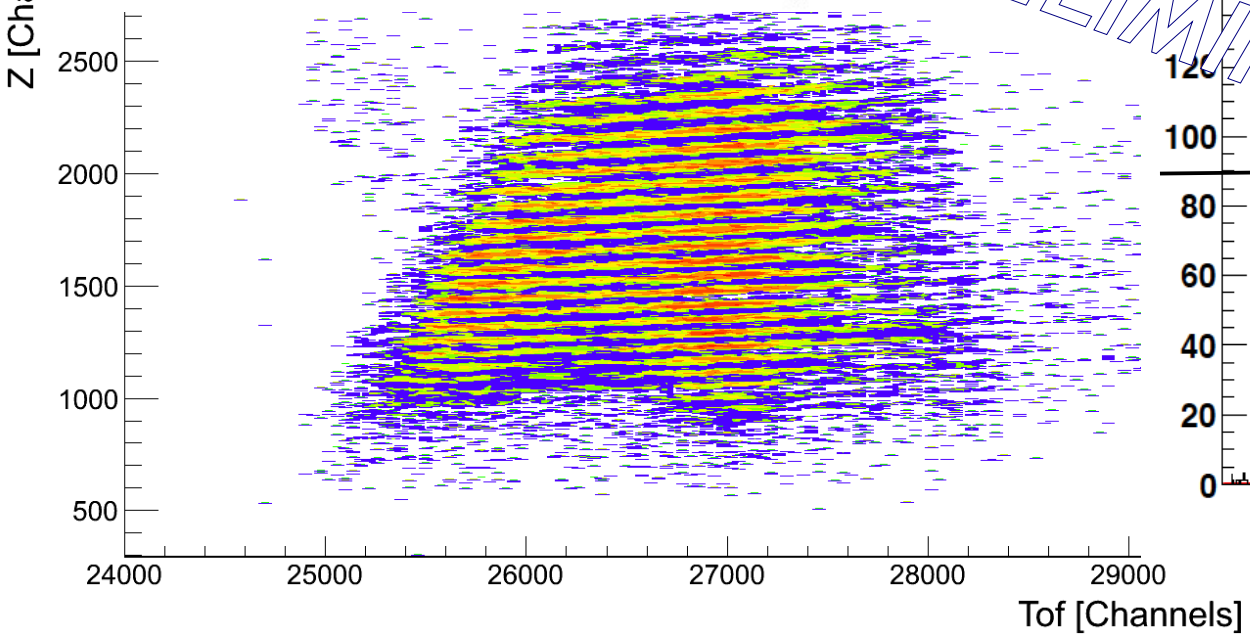
CEA Bruyeres, GSI, IPN Orsay, CENBG, Univ. Vigo, Santiago de Compostela, CEA Saclay, GANIL, Univ. Chalmers and Univ. West Scotland.

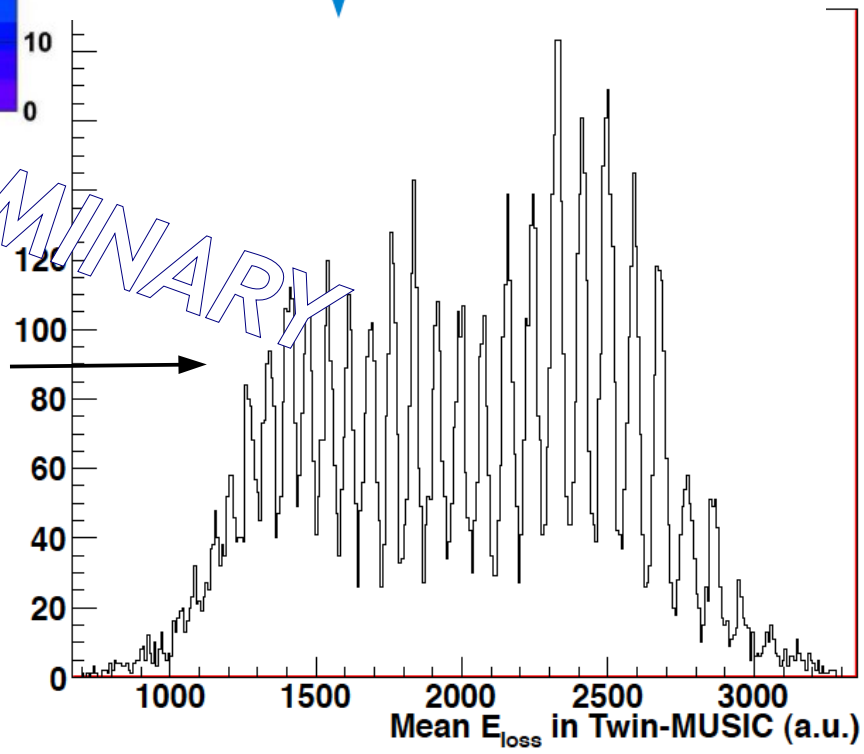
Spokepeople: J. Taieb and J. Benlliure.

SOFIA fission studies... online snapshots



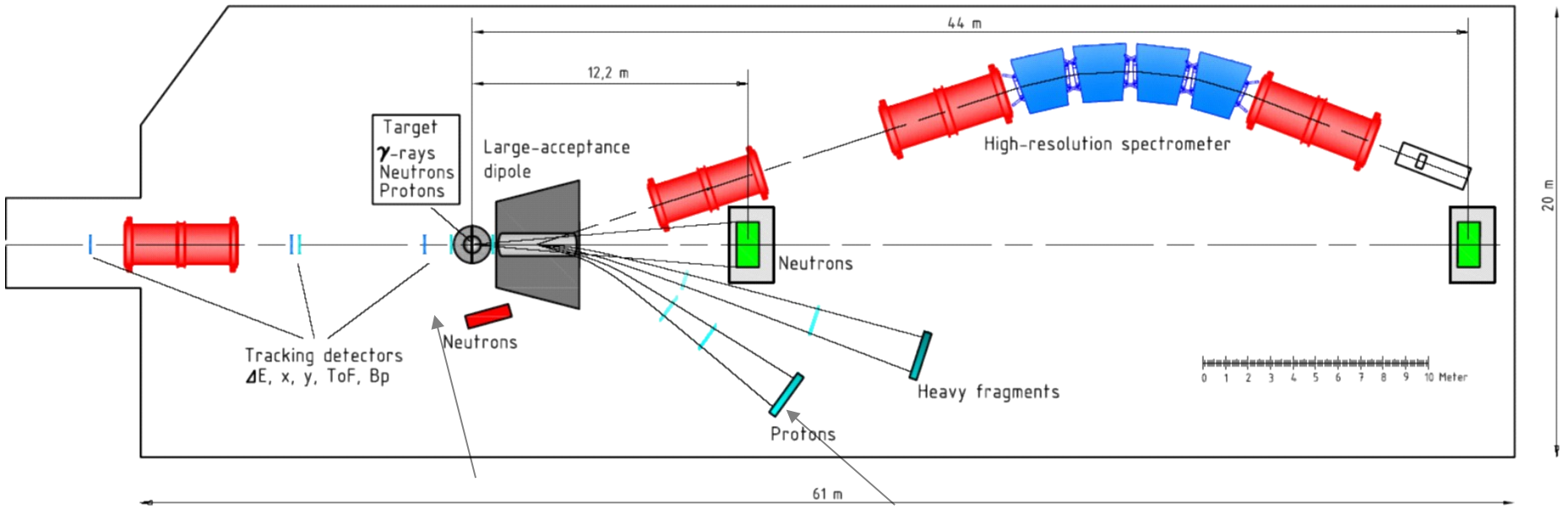






R³B: Reactions with Relativistic Radioactive Beams

More than 300 scientists from institutions in 23 countries



R³B (Reactions with Radiactive Relativistic Beams):

- Beam, proton and fragment ToF & tracking detectors.
- Silicon arrays around target for recoils.
- **Large acceptance** superconducting dipole.
- **High resolution** neutron detectors.
- **High efficiency** calorimeter/gamma spectrometer.

http://www.gsi.de/forschung/kp/kp2/collaborations/R3B

R³B Physics programs comprehends:

- Knockout: evolution of shell structure, clusters, ...
- QFS: structure functions, N-N correlations, ...
- Total absorption: halo nuclei, nuclear radius, ...
- Elastic scattering: nuclear density, ...
- EM excitations: astrophysical S factors, ...
- Fission: structural and dynamic properties, ...
- Spallation, fragmentation, multifragmentation, ...

CALIFA: the R^{3}B calorimeter and gamma spectrometer

CALIFA: the R3B CALorimeter for In Flight detection of γ rays and high energy charged pArticles.

CALIFA Working group (stablished since 2005):

- **Conceptual & mechanical design**: Univ. Santiago de Compostela, Univ. Vigo.
- **Crystal and photosensors**: Univ. Santiago de Compostela, Univ. LUND, IEM-CSIC, Univ. Chalmers.
- **Simulations**: Univ. Santiago de Compostela, Univ. LUND, IEM-CSIC, Univ. Lisboa, EMMI-GSI.
- **Electronics**: T.U. München, IEM-CSIC, Univ. Santiago de Compostela.
- **Slow control**: T.U. Darmstadt, IEM-CSIC, T.U. München.
- **DAQ**: GSI, T.U. München (Common task within R^{3}B).

Univ. Santiago de Compostela (Spain)

Univ. LUND (Sweden)

Univ. Vigo (Spain)

Univ. Lisbon (Portugal)

T. U. München (Germany)

ExtreMe Matter Institute (Germany)

Univ. Frankfurt (Germany)

Univ. Chalmers (Sweden)

IEM - CSIC (Spain)

T. U. Darmstadt (Germany)

GSI Helmholtzzentrum für Schwerionenforschung (Germany)

What makes CALIFA an unique instrument?

The CALIFA requirements comprise:

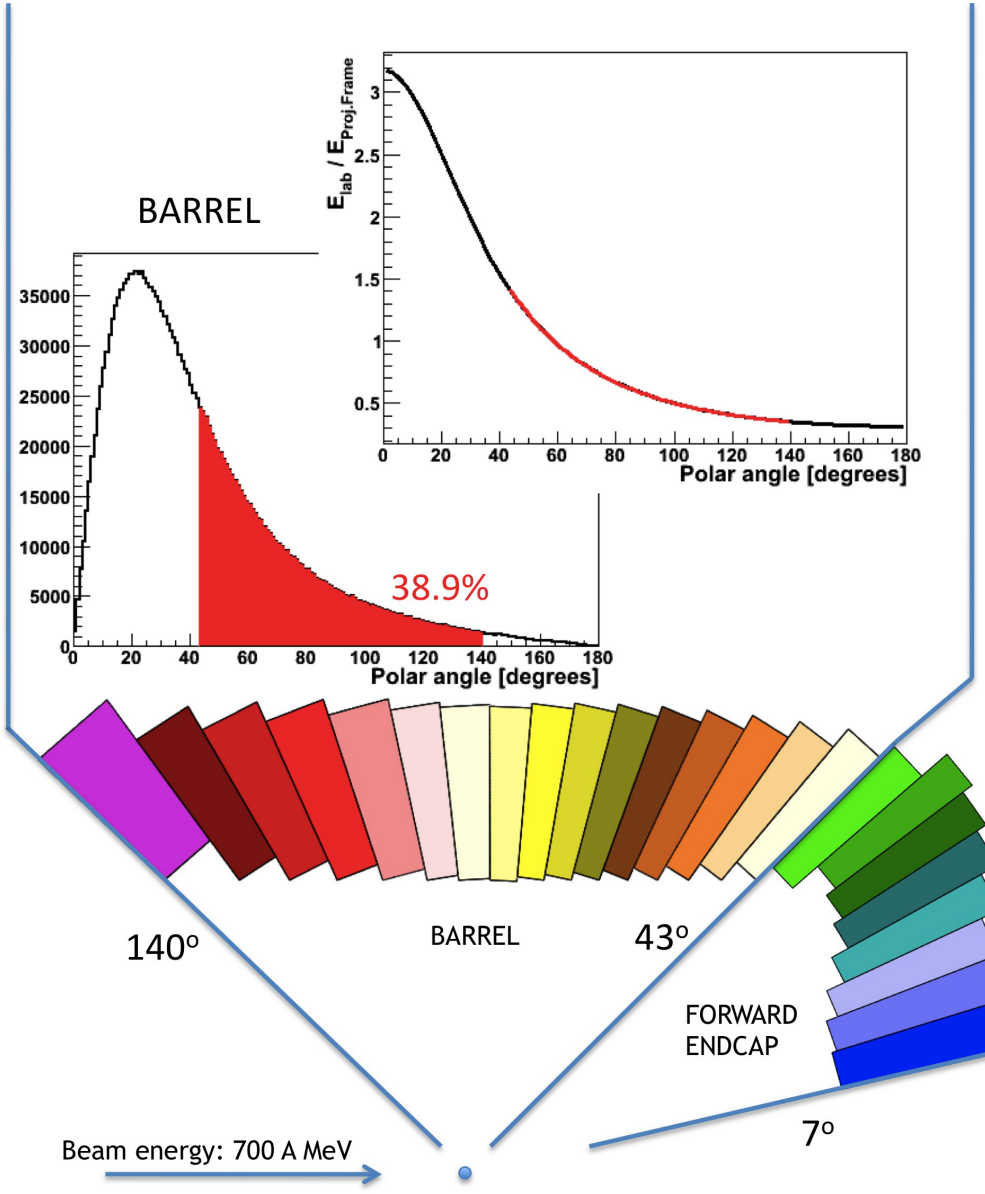
- Intrinsic **photopeak efficiency:** **40% up to E = 15MeV** projectile frame.
- A **γ ray sum energy resolution:** **$\Delta(E_{Sum})/<E_{Sum}>$~10%** for 5 γ rays of 3 MeV.
- A **γ ray energy resolution:** **ΔE/E~5-6%** (FWHM) for 1 MeV γ rays.
- **Calorimeter** for high energy light charged particles (LCP): up to 320 MeV in Lab.
- **LCP energy resolution:** **$\Delta E_p/E_p$<1%** up to 300 MeV.
- Proton – γ ray **separation**: for 1 to 30 MeV.

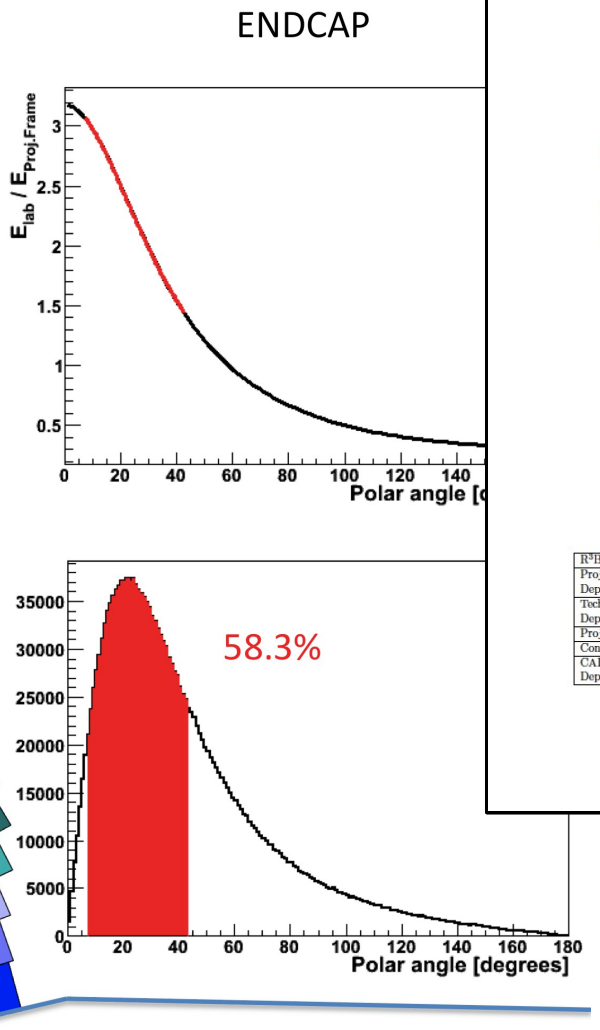
… and additionally CALIFA should offer:

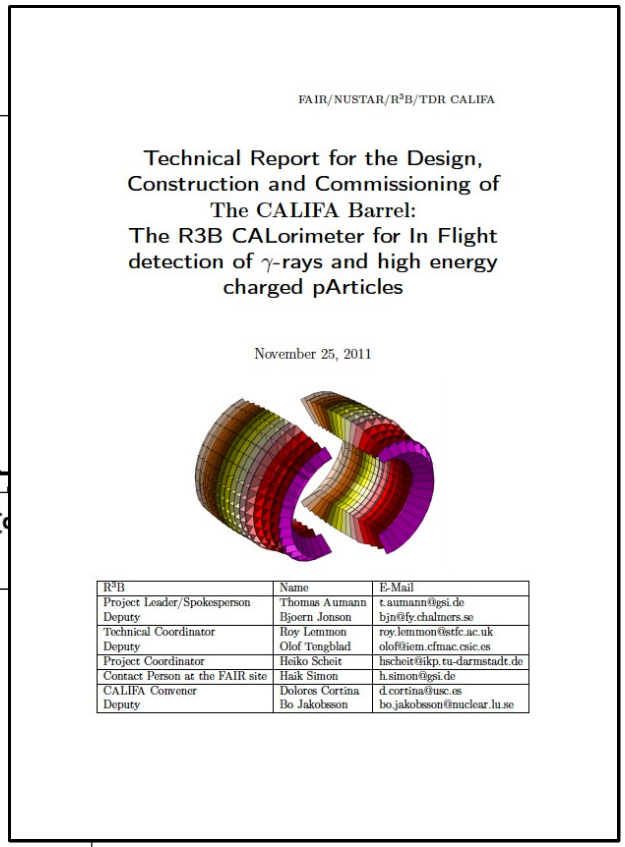
- The appropriate volume coverage, surrounding the reaction chamber and the inner (silicon) tracker detectors.
- A reduction of dead layers to increase efficiency.
- A solution to the problems associated to the particular γ ray kinematics.
- A reasonable cost.

Detector based on the use of performant CsI(Tl) scintillation crystals and LA-APDs photosensors

CALIFA conceptual design







FAIR/NUSTAR/R³B/TDR CALIFA

Technical Report for the Design, Construction and Commissioning of The CALIFA Barrel: The R3B CALorimeter for In Flight detection of γ-rays and high energy charged pArticles

November 25, 2011

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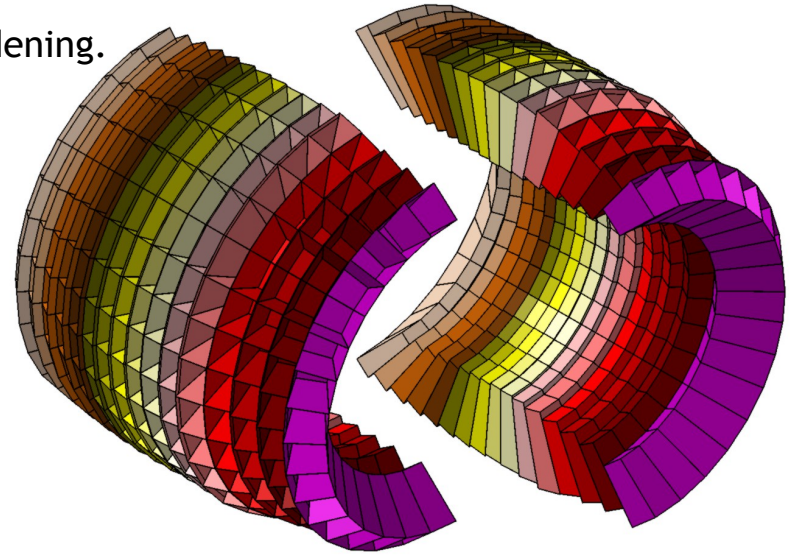
CALIFA Convener	Dolores Cortina	d.cortina@usc.es
Deputy	Bo Jakobsson	bo.jakobsson@nuclear.lu.se

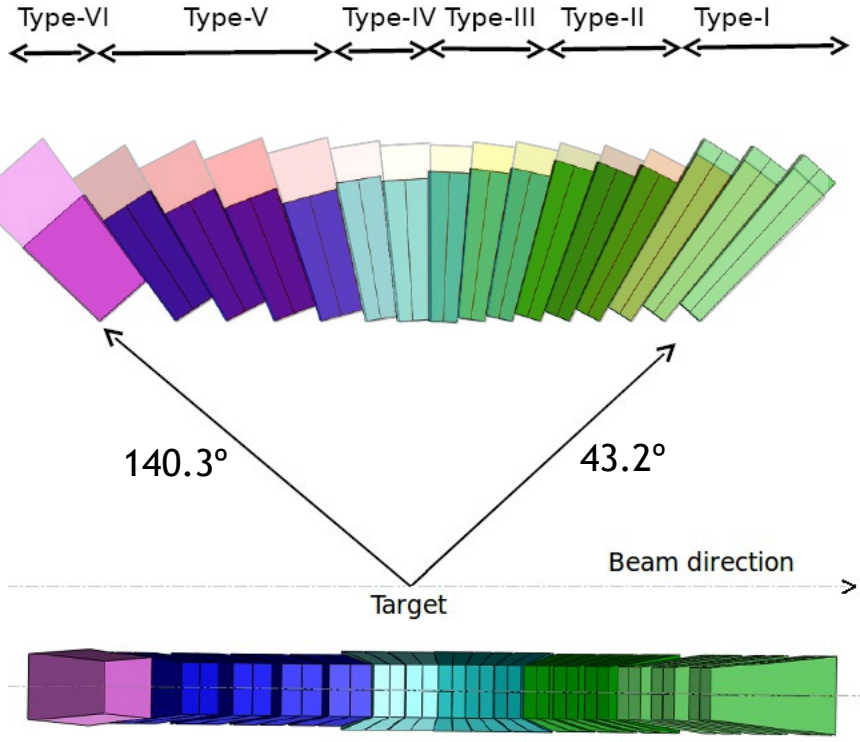
H. Alvarez *et al.* NIM B 266 (2008) 4616-4620

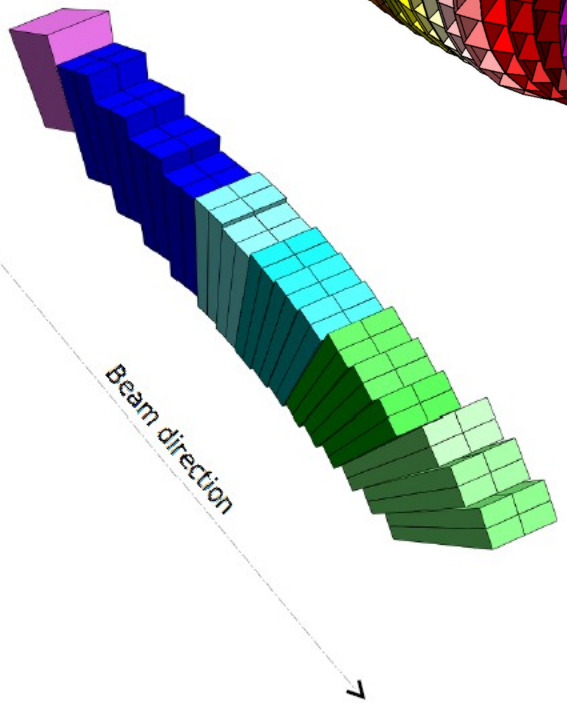
CALIFA BARREL design

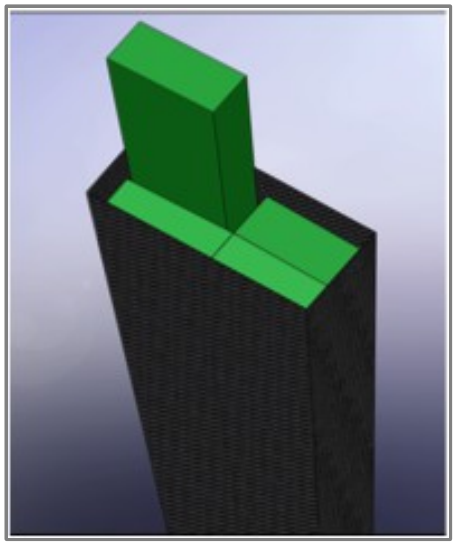
The CALIFA BARREL design comprises:

- A set of finger-like CsI[Tl] crystals with LAAPD readout.
- Sufficient granularity to ensure a reduced Doppler broadening.
- The length of the crystals secures QFS proton detection.
- Very thin carbon fiber alveoli in a honeycomb.
- A compact 1 m^3 detector.





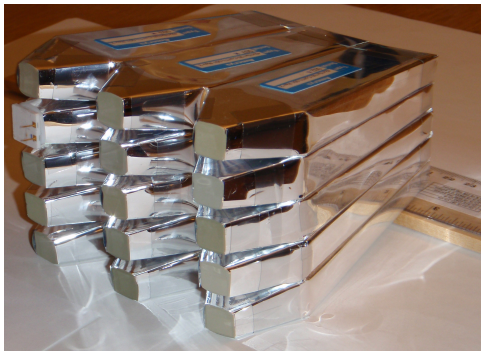




R&D on CsI[Tl] + LAAPD

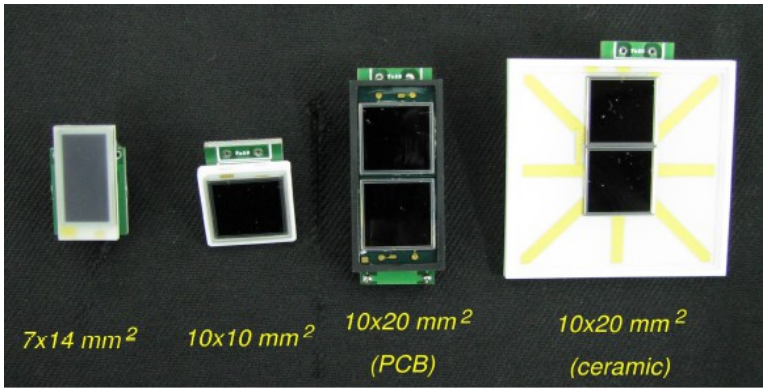
CsI[Tl] crystal optimisation:

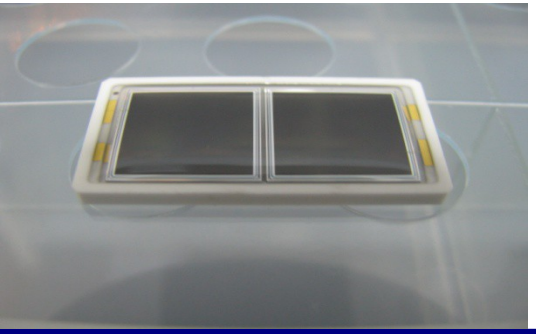
- Comparative study of different providers: AMCRYS, IMP Lanzhou, ...
- Study on light output non-homogeneity.
- Research on minimum interacting wrapping: ESR (3M) + thin carbon fiber alveoli). Crucial for light charged particle calorimetry!!
- Optimization in light yield collection:
  - guide light, optimum angle/shape for light collection;
  - maximum LAAPD exit face.
- Crystal + LAAPD coupling.



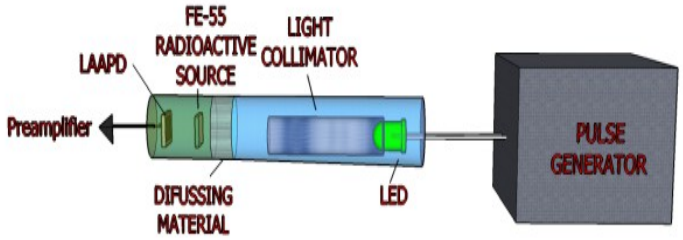
LAAPD optimisation (Hamamatsu S8664-1010):

- Dark current characterization.
- Optimum working voltage.
- LAAPD contribution to the system resolution.
- Development of larger sensors.
- Search for alternative providers (Laser Components).



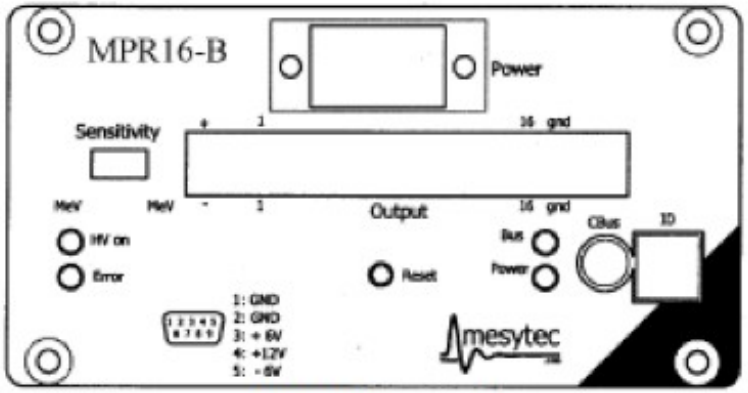


M. Gascón *et al*. IEEE Trans. Nucl. Sci. 55 (2008) 1259
H. Alvarez *et al*. NIM B 266 (2008) 4616
M. Gascón *et al*. IEEE Trans. Nucl. Sci. 56 (2009) 962
M. Gascón *et al*. IEEE Trans. Nucl. Sci. 57 (2010) 1465

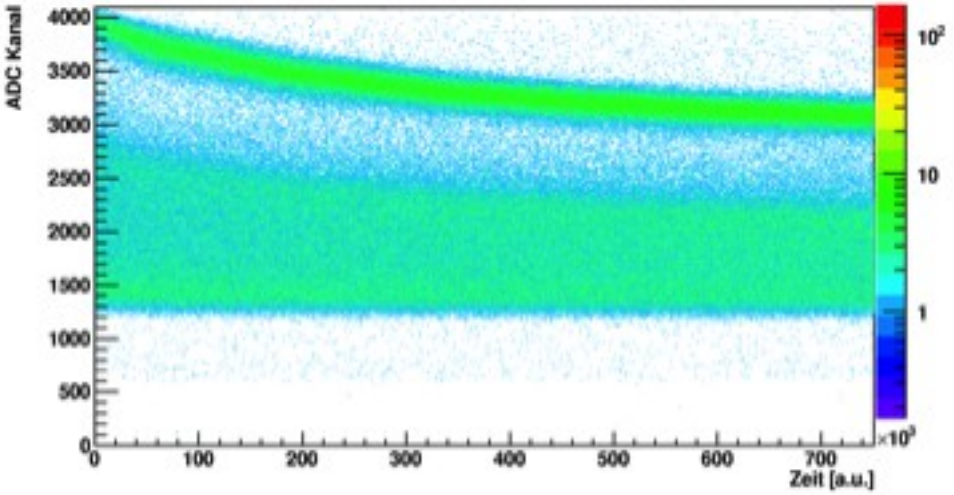


Electronics based on Mesytec preamplifier concept:

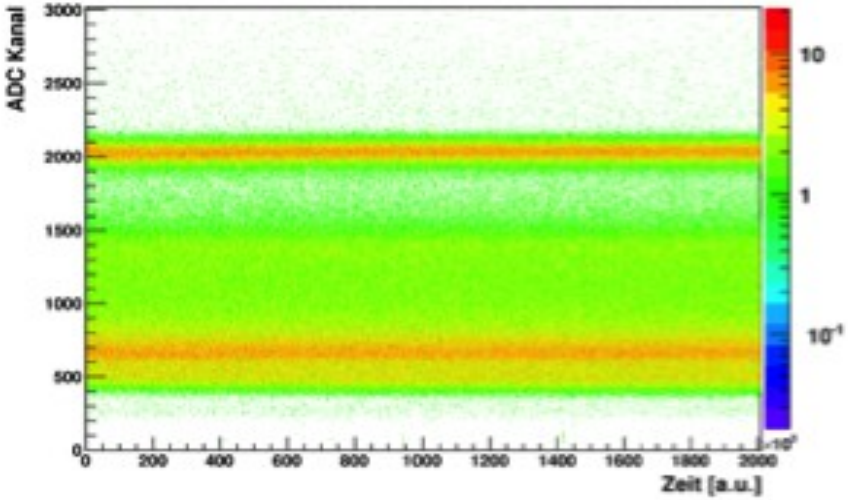
- 16 channels preamplifiers with individual bias.
- Test input for electronics drift monitorization.
- Temperature sensor with hardware temperature compensation system.
- The high temperature gain drift of the APDs are fully corrected by adapting the bias voltage.



MPR16-B front panel



Without hardware temperature compensation



With hardware temperature compensation

Beam test of different prototypes

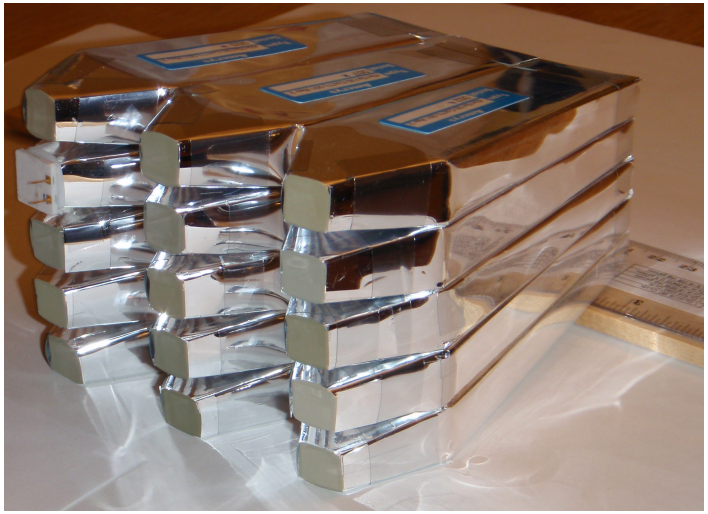
Test of CsI[Tl]+LAAPD CALIFA BARREL prototypes:

ProtoZero: 15 crystals, 13 cm long, 1x1cm^2 LAAPD

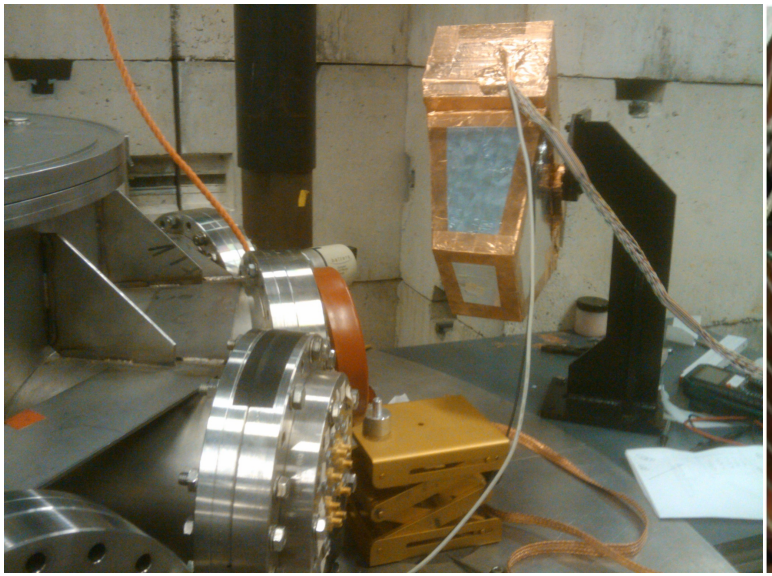
- High-energy γ rays, CMAM (Madrid), April 2009.
- High-energy protons, Uppsala, June 2009.
- High-energy tagged γ rays, NEPTUN/TUD, December 2009.

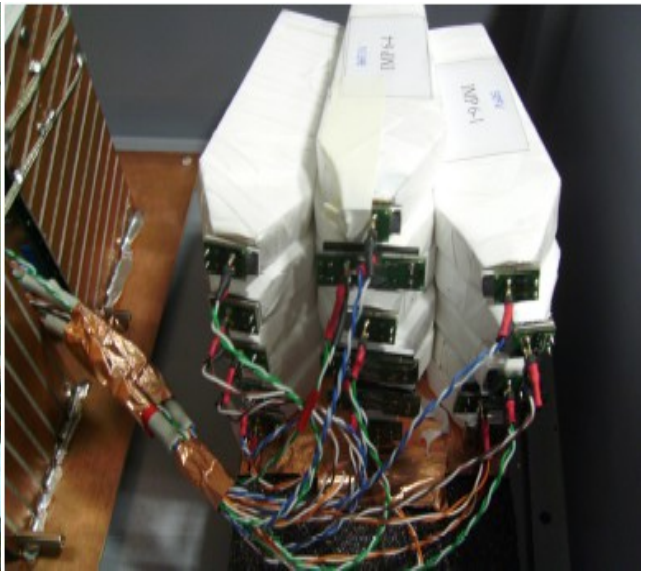
DemoZero: 32 crystals, 18 cm long, 2x1cm^2 LAAPD

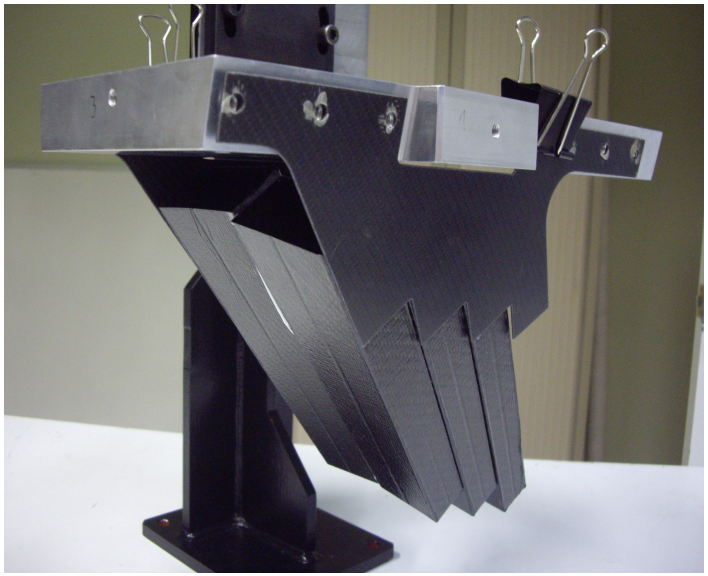
- Light charged particles, GSI, November 2010.
- Low energy protons, TUM, June 2011 (FPGA tests).



- D.D. DiJulio et al., NIM A, 612 (2009) 127
- M. Gascón. *Prototype of a new calorimeter for the studies of nuclear reactions with relativistic radioactive beams*. PhD thesis, Universidade de Santiago de Compostela, 2010.



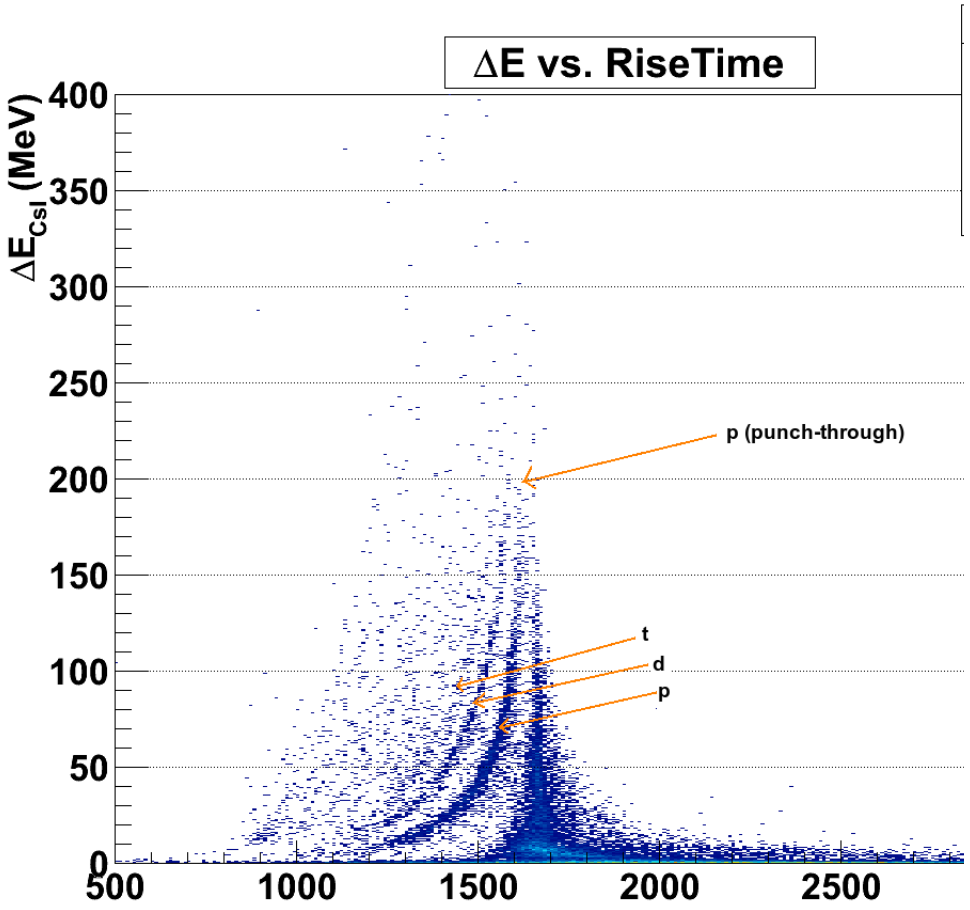


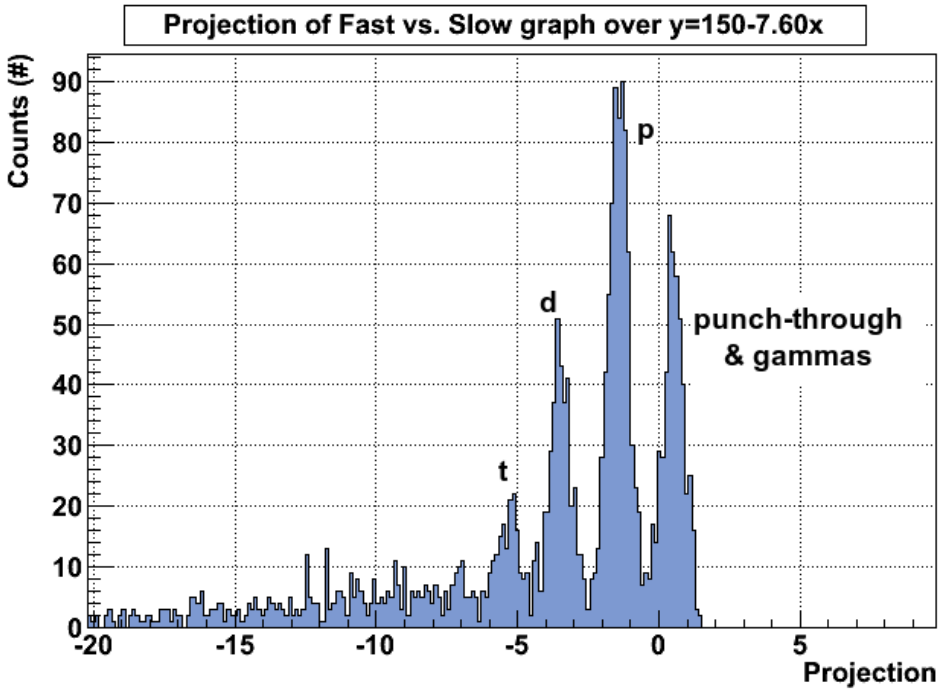


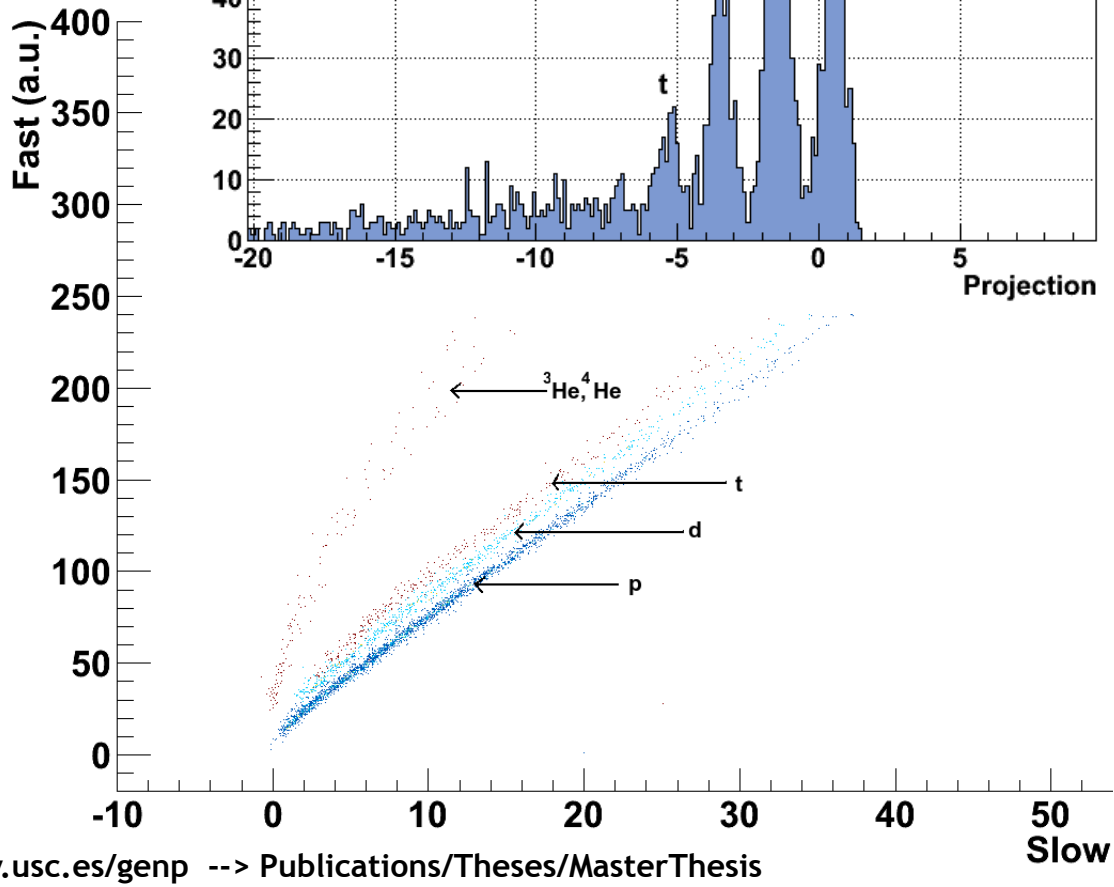
Light charged particle ID capabilities

CsI[Tl] ID by pulse analysis:

- Test with ProtoZero crystals.
- AsyEos test: $^{197}Au^{65+}$ @ 400 A MeV on a Pb target.
- PSA using Rise Time vs. ΔE and Fast vs Slow components (optimized with a double MWD over the derivative of the integrated charge).

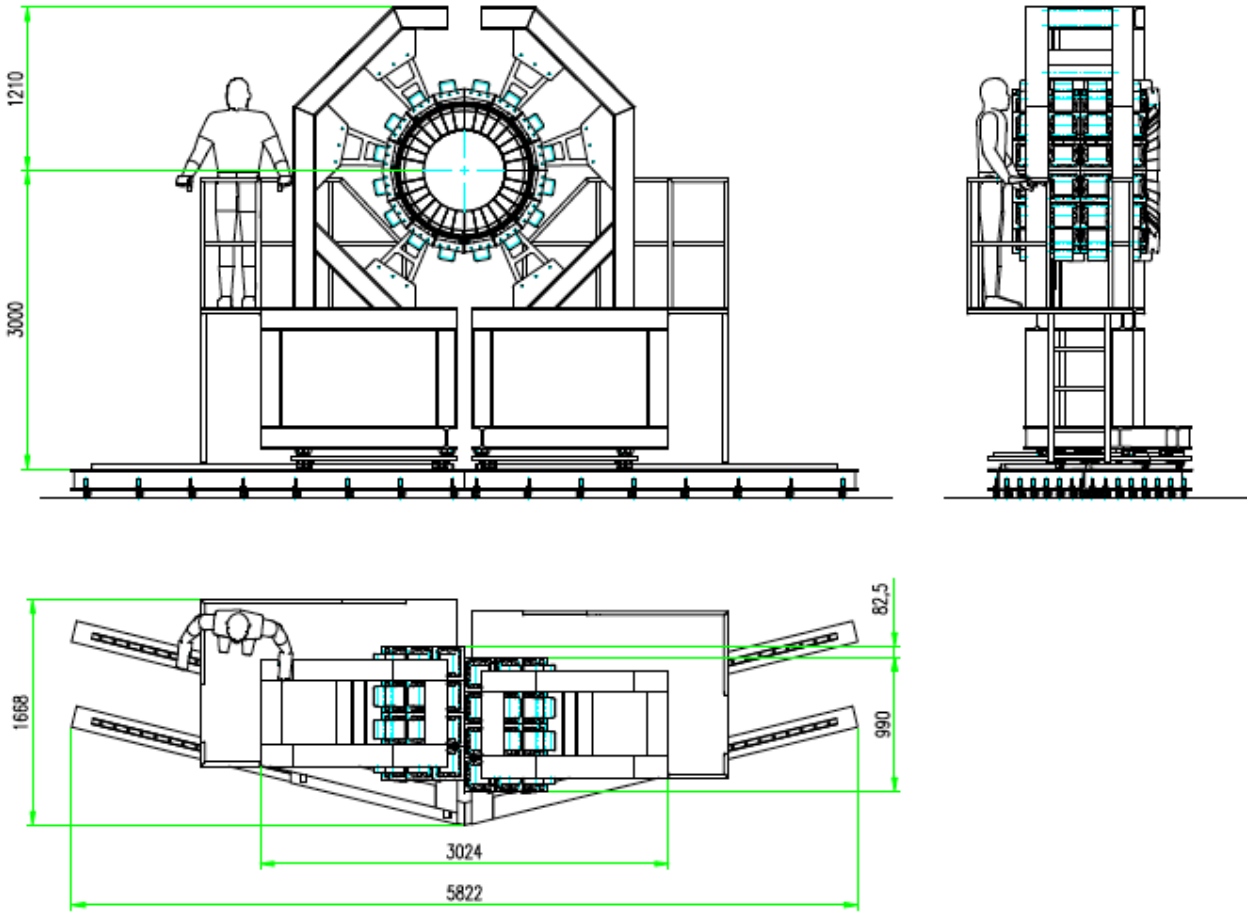


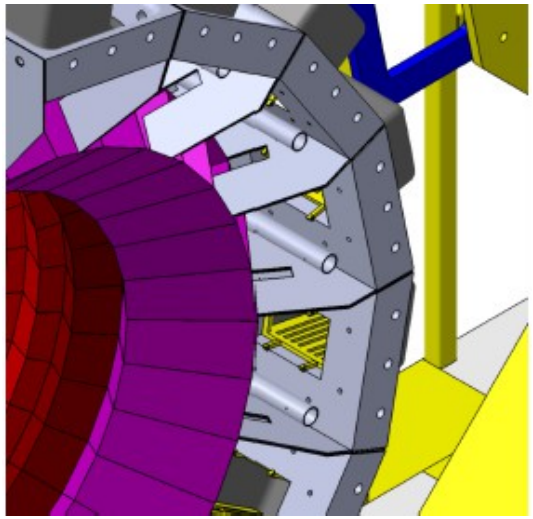


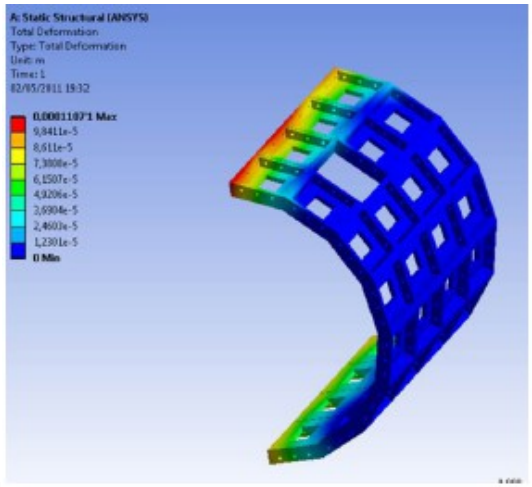


Diego Ramos Doval, Master Thesis, USC. (Available at http://www.usc.es/genp --> Publications/Theses/MasterThesis

CALIFA BARREL mechanics







The CALIFA BARREL engineering and mechanical design completed:

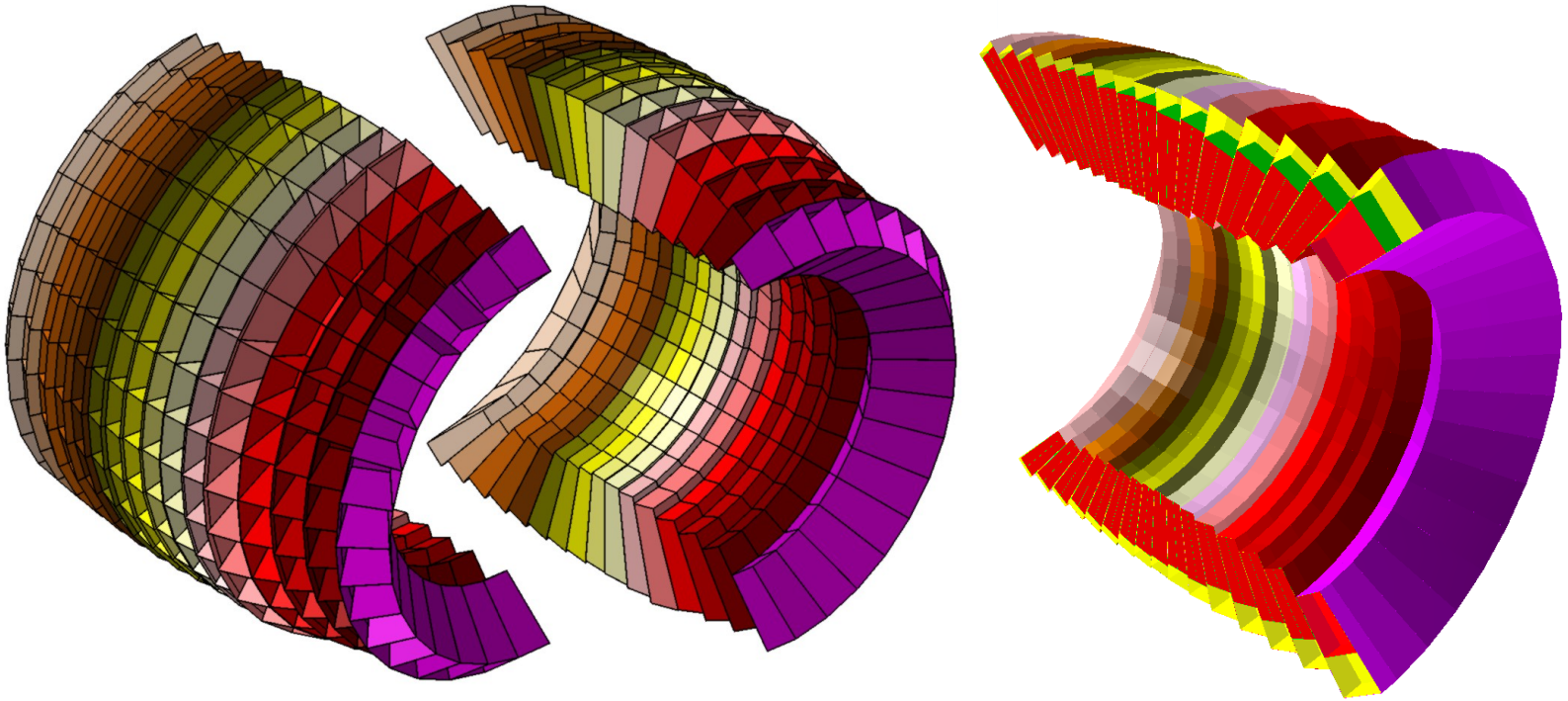
- Alveolar carbon fiber structure with self supported pockets glued with epoxy.
- Modular aluminum structure covering the preamplification electronics.
- Linear guides for inner access, adjustable total heigth.
- Self supporting calorimeter halves.

CALIFA BARREL simulation

Crystals	1952
Crystals per ring	64 (32)
Crystals by polar direction	31
Crystals by alveolus	4 (1)
Alveoli	512
Alveoli by ring	32
Alveoli by polar direction	16

Complete inventory of matter in simulation:

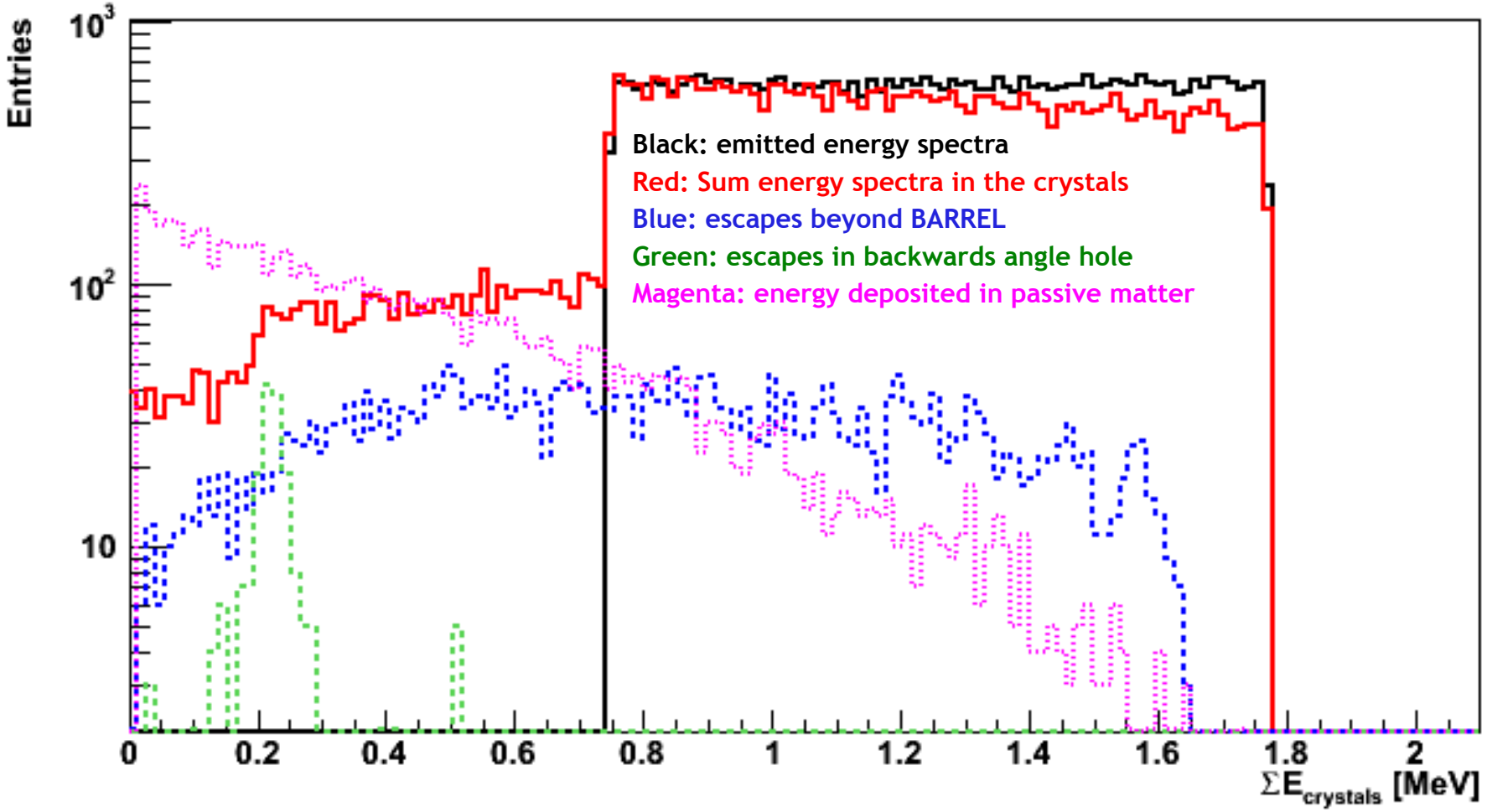
- Crystals, variable thickness wrapping
- Alveoli (also variable thickness), spacers, tabs, ...
- Inner components (chamber, inner detectors, ...)



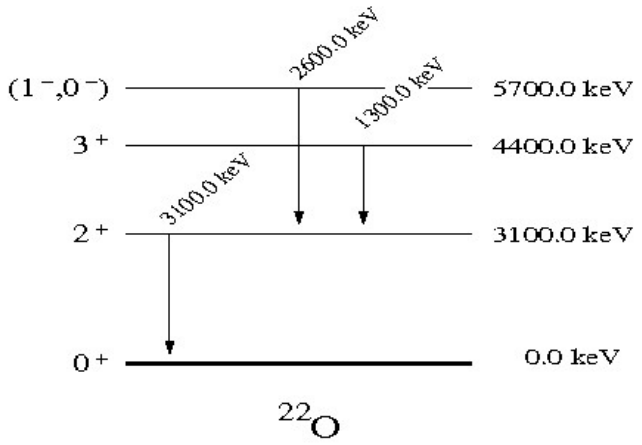
Simulation results: reconstructing the full energy

Energy spectra and losses in different parts of the CALIFA BARREL:

- The plot shows the results for 1 MeV γ rays in the projectile frame, emitted toward the BARREL.
- The black spectra reflects the laboratory energies in the BARREL geometrical acceptance.

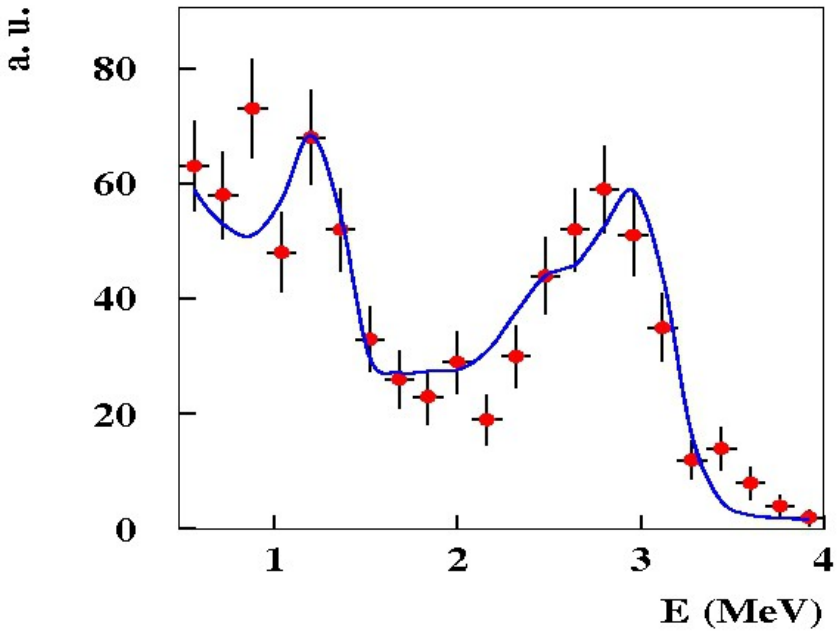


Selected Physical cases: γ ray spectroscopy

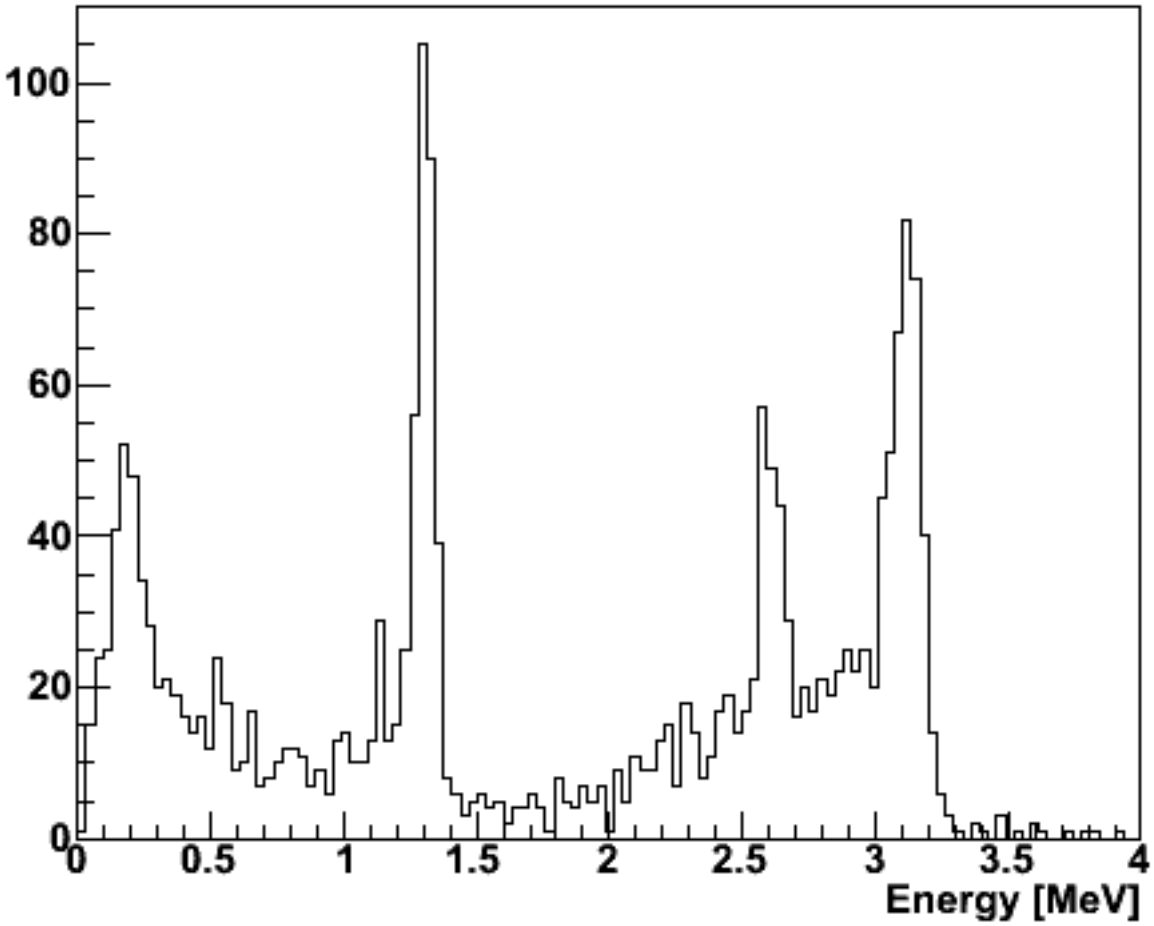


CALIFA BARREL as a high resolution spectroscopy: the ^{22}O nucleus.

- Experimental spectra obtained with NaI detectors at FRS:GSI.
- CALIFA BARREL spectra mimics the statistics to demonstrate the high resolution expected in nuclear spectroscopy.

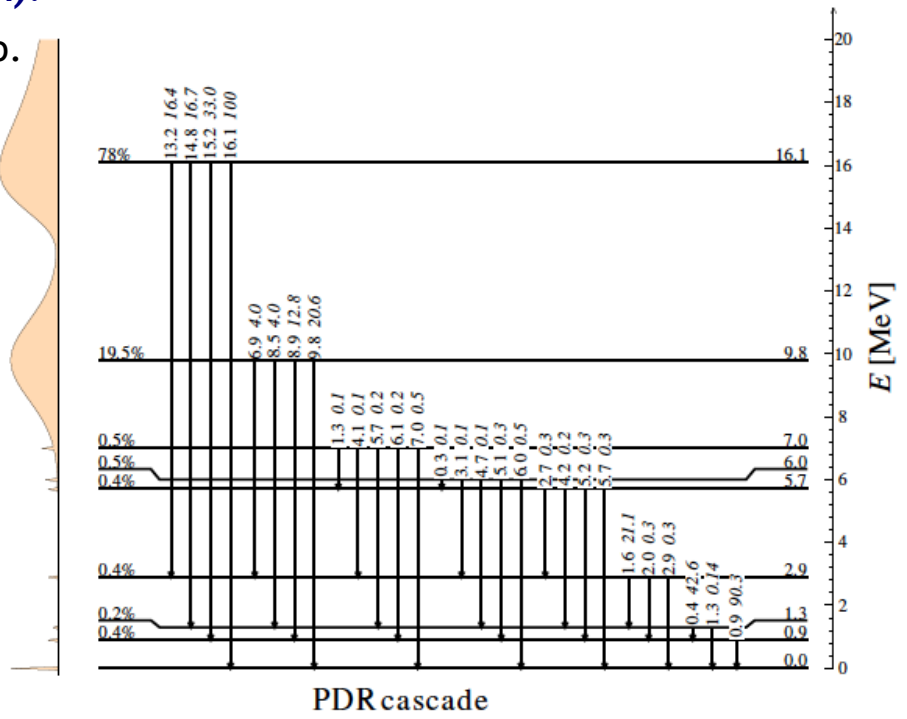


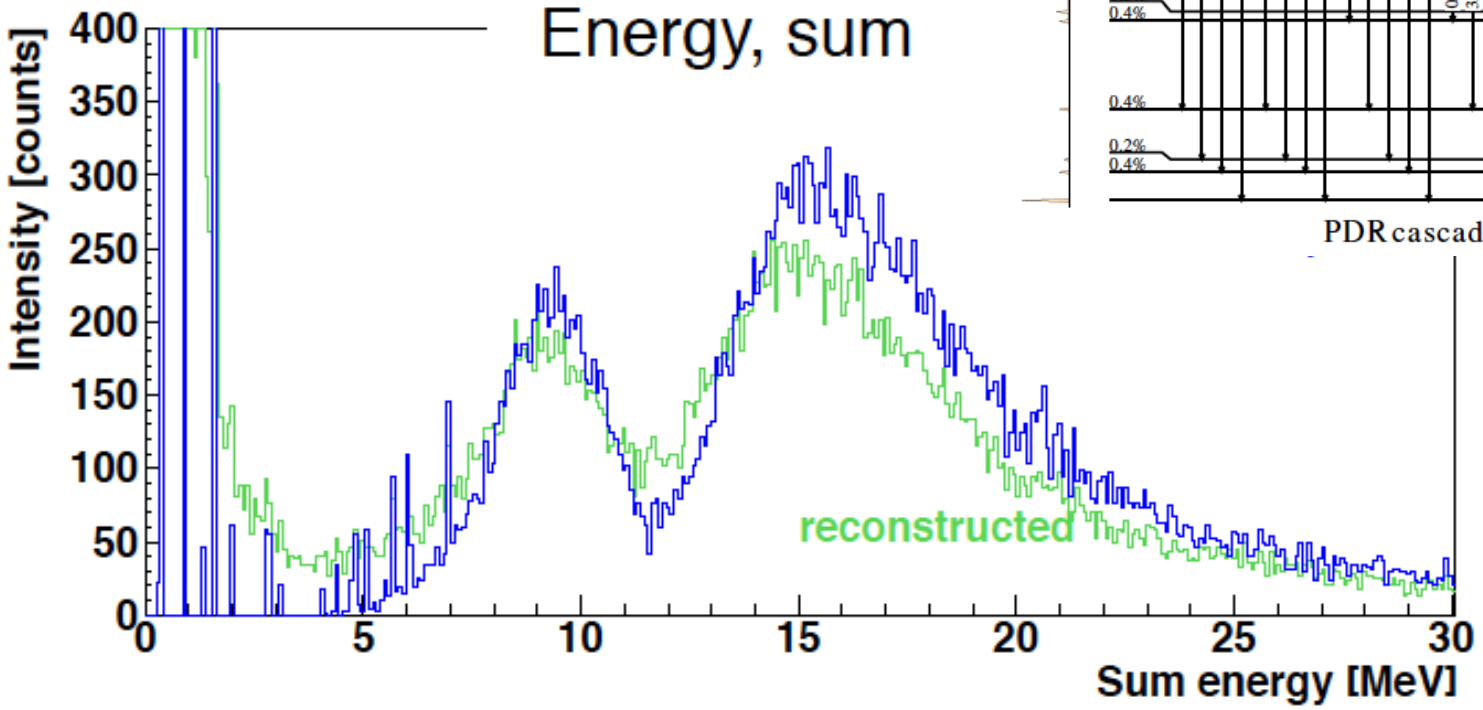
D. Cortina *et al*. Phys. Rev. Lett. 93 (2004) 062501



CALIFA BARREL in a GDR-PDR case (adapted from ^{132}Sn):

- Relative strength of GDR and PDR mimics the exp. results, but only gamma decays are allowed.
- Reconstructed photon energies are summed, determining the total excitation energy.
- Distorsions come from limited efficiency for high energy γ rays or in cascades.





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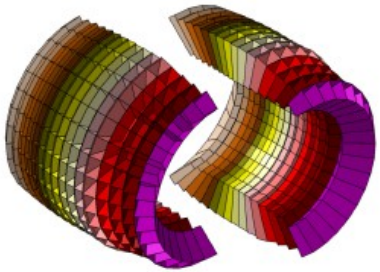
Summary + Outlook

FAIR/NUSTAR/R^{3}B/TDR CALIFA

Technical Report for the Design, Construction and Commissioning of The CALIFA Barrel: The R3B CALorimeter for In Flight detection of γ-rays and high energy charged pArticles

November 25, 2011



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On the path to R^{3}B: a versatile setup for investigating reactions with relativistic exotic nuclei.

- Analysis of the first experiment ongoing.
- Scheduled test experiments with the new detectors (demonstrators, prototypes) for 2013/2014

  -> See talk of I. Gasparic today about NeuLAND!

CALIFA as a main component of R^{3}B:

- R&D phase completed for the BARREL.
- BARREL Technical Design Report ready.
- Demonstrator will be ready for 2013/2014 tests.

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