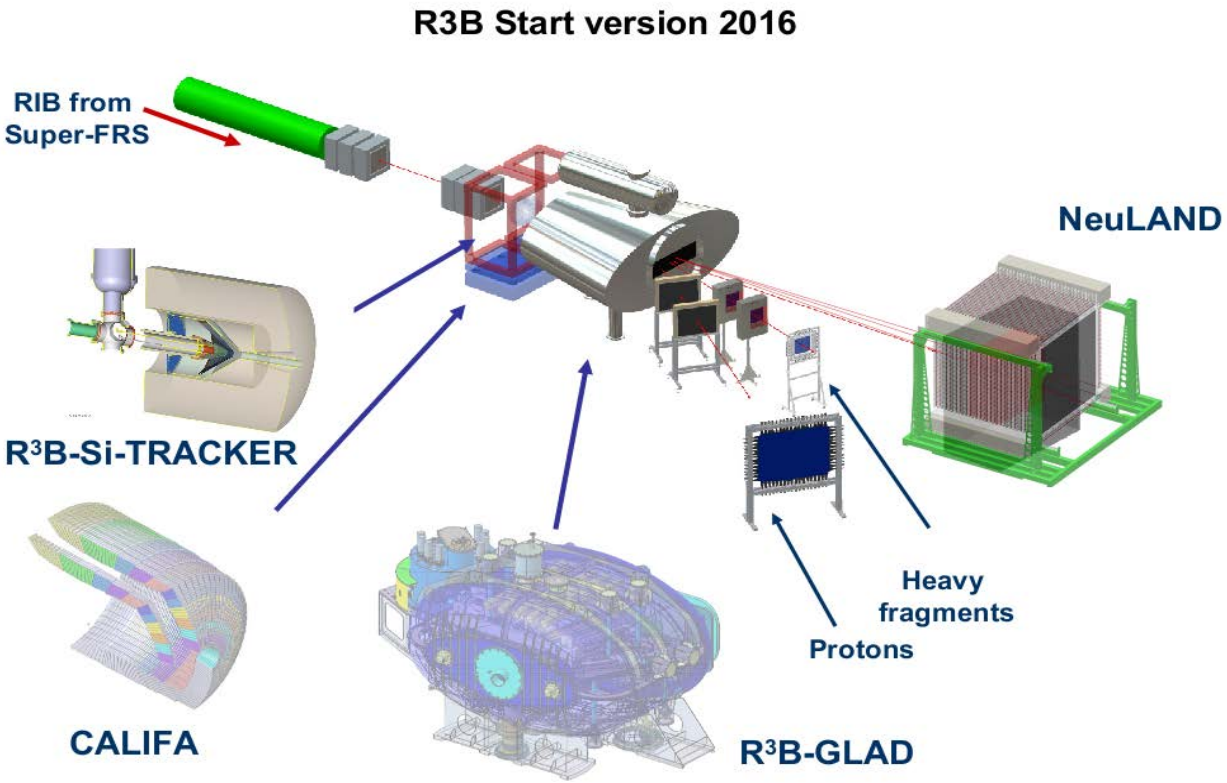
CALIFA for R3B@FAIR – a status report



P.Golubev and J.Cederkäll (CALIFA wg dpty)
on behalf of the

CALIFA Working Group:

USC-IEM-UVigo

GSI-TUM
EMMI-TUD

Chalmers
Lund

CFNUL

JINR - NRC

CALIFA a calorimeter for R3B@FAIR

CALorimeter for **I**n **F**light detection of γ-rays and light charged p**A**rticles

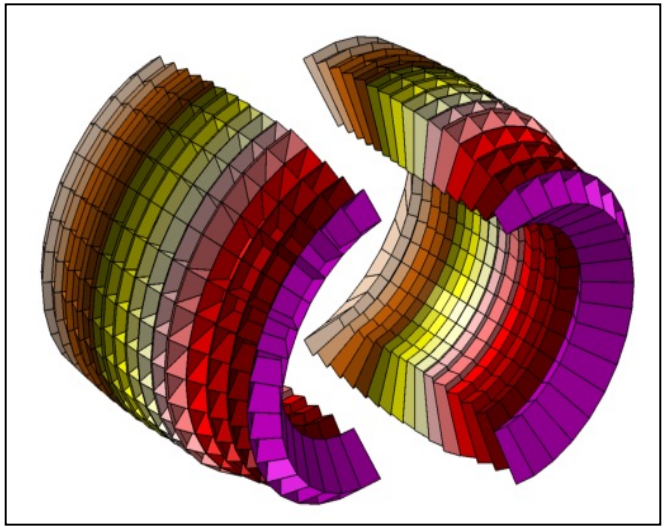
A versatile detector for a multi-purpose experiment

→ Huge dynamic range (γ: 100 keV - 20 MeV and p: 1-320 MeV)

It sourounds the R3B target. The inner volume of CALIFA is occupied by a very complex Si Tracker system.

R3B has a very broad experimental program:

- Nuclear structure far from stability
- Fission studies
- Reactions of astrophysical interest
- EOS of asymmetric nuclear matter



CALIFA would be a key detector in many of these studies.

Scientific requirements for CALIFA@FAIR

The required functionality of CALIFA will vary greatly from one case to another.

Calorimetrer	Intrinsic photopeak efficiency	40% (up to Eɣ=15 MeV projectile frame)
	Gamma sum energy resolution $\Delta(E_\gamma sum)/<(E_\gamma sum)>$	< 10% for 5 γ rays of 3 MeV
	Calorimeter for high energy Light charged particles	Up to 320 MeV in lab system
Spectrometer	Gamma energy resolution	~5-6% (FWHM at Eγ=1 MeV)
	Light charged particles resolution	~2%
	Proton-ɣ ray separation	For 1 to 30 MeV

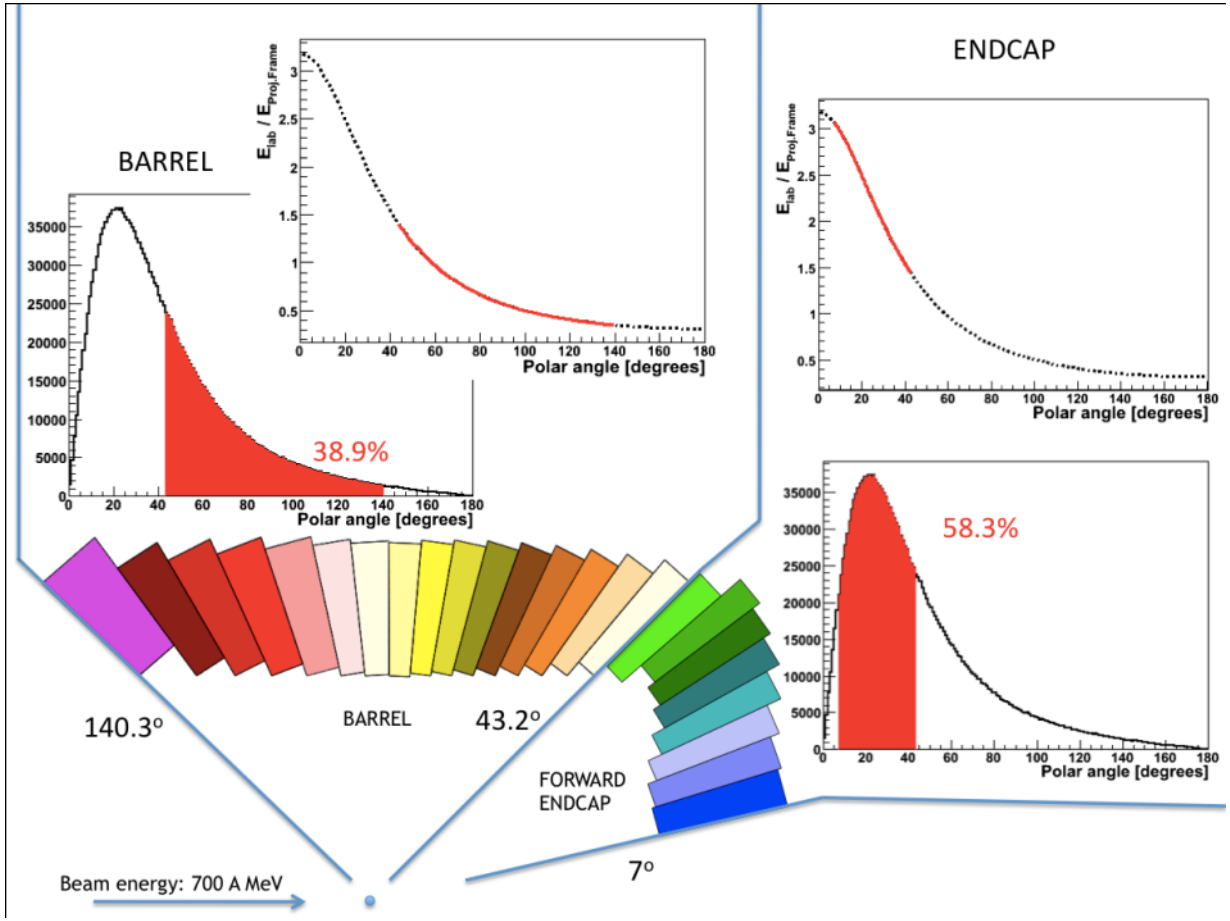
- Performant scintillator materials and photosensors (CsI(Tl) + LAAPD)
- Granular detector: Few thousands of finger-like crystals
- Minimum dead volume: compact arrangement + carbon fiber alveoli support
- The geometrical design is governed by the kinematics of particles emitted by relativistic sources
- The detector is splited into a Barrel (backward angles) and a Forward Endcap (forward angles)

CALorimeter **I**n **F**light detection of γ and charged p**A**rticles

- Design dominated by the kinematics of particles emitted by relativistic sources
- The detection of low energy g-rays together with high energy charged-particles

→ huge dynamic range

Detector splits in two sections : BARREL and ENDCAP



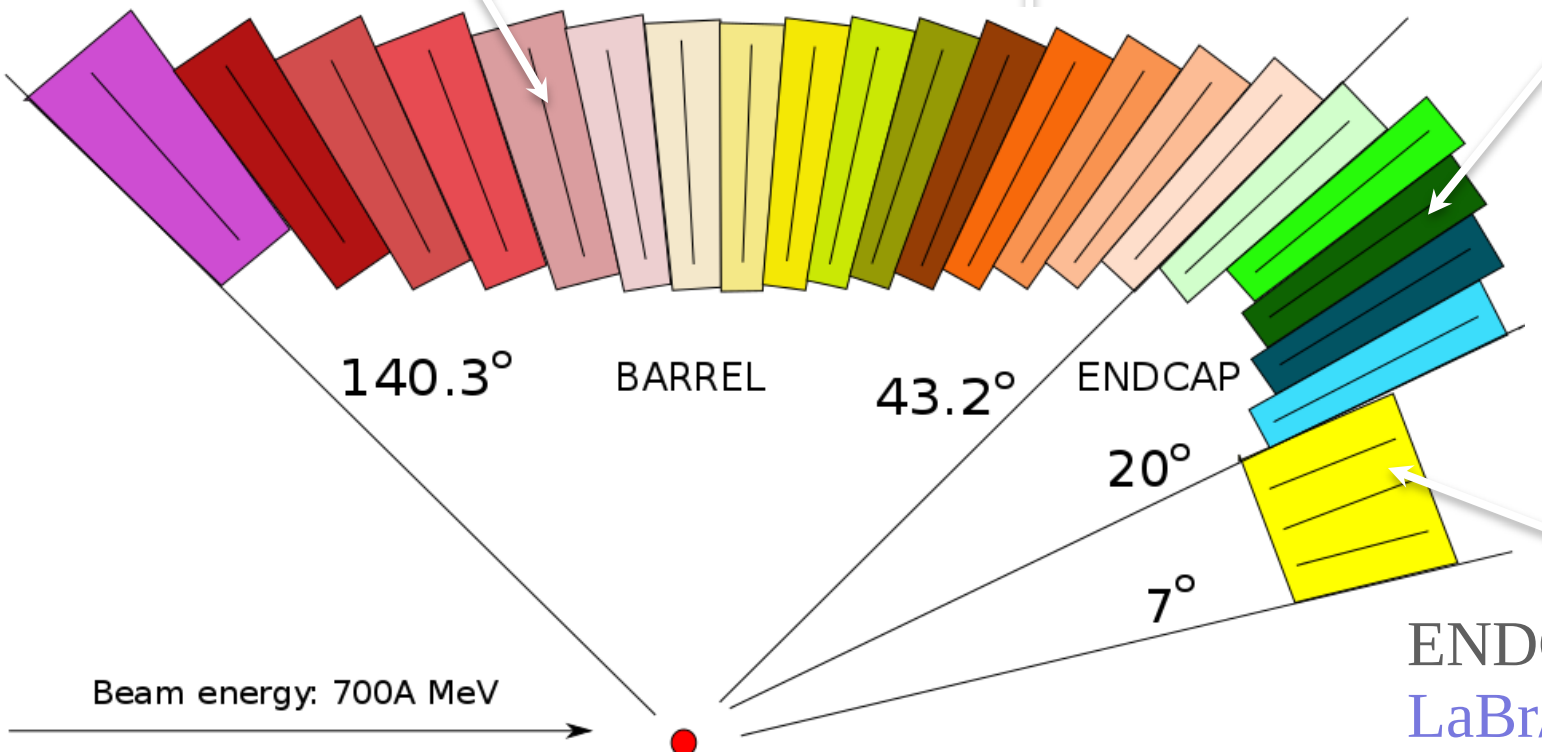
Technical challengies

- Performant scintillator materials (CsI(Tl), phsw LaBr/LaCl) and photosensors adapted to the different needs over the angular range
- Granular detector: few thousands of finger-like crystals
- Minimum dead volume: compact arrangement + carbon fiber alveoli support

CALorimeter **I**n **F**light detection of γ and charged p**A**rticles

BARREL
CsI(Tl) + LAAPD

ENDCAP-iPHOS
CsI(Tl) + LAAPD



ENDCAP- CEPA
LaBr/LaCl+PMT

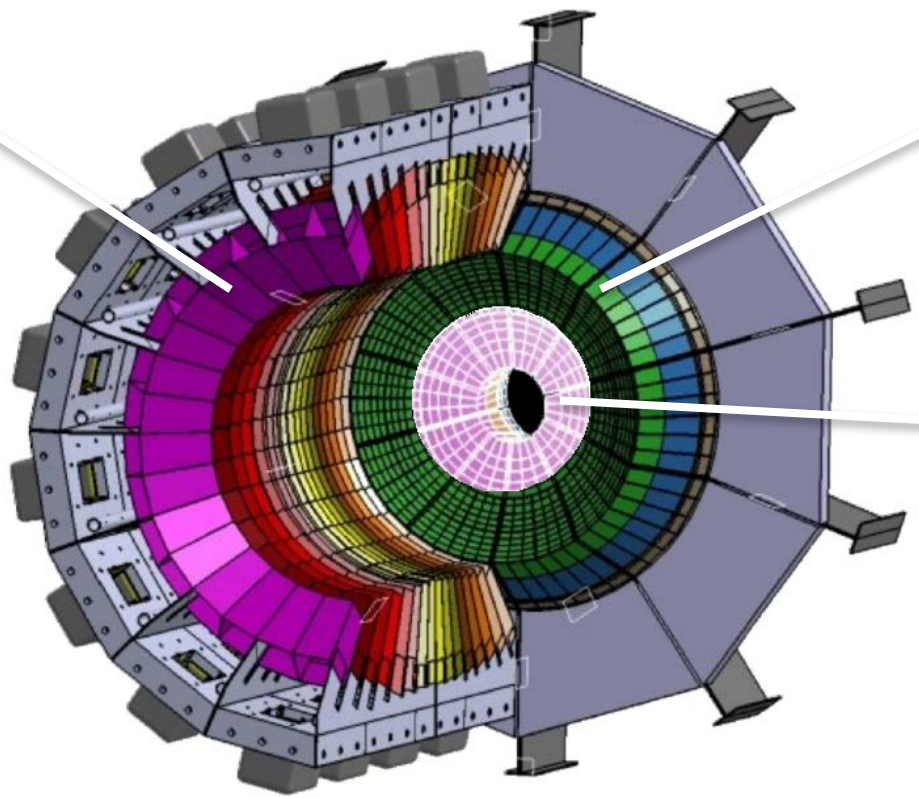
CALorimeter **I**n **F**light detection of γ and charged p**A**rticles

The solution: C^3 (CALIFA Combined Concept)

BARREL TDR aproved by
FAIR management January 2013

BARREL
CsI(Tl) + LAAPD

ENDCAP-iPHOS
CsI(Tl) + LAAPD

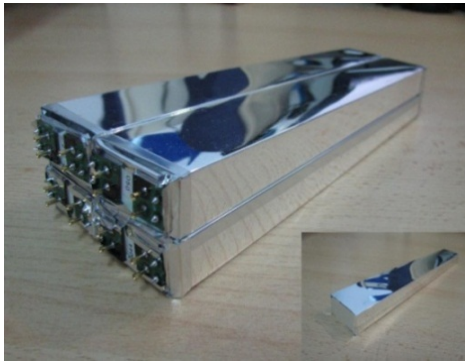


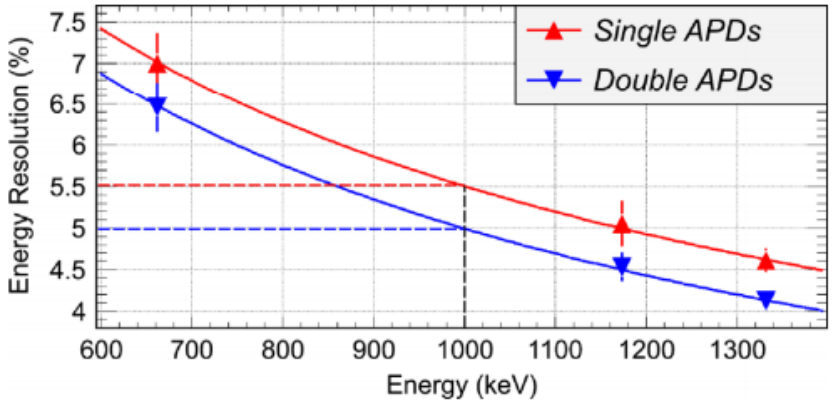
ENDCAP- CEPA
LaBr/LaCl+PMT

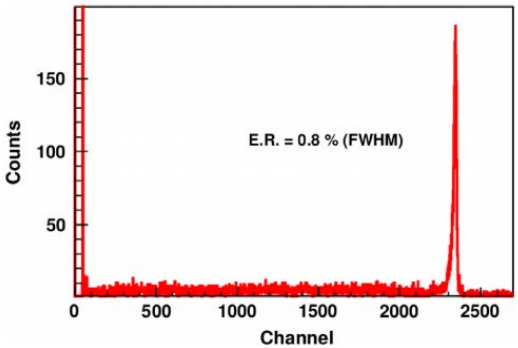
ENDCAP TDR expected end of 2014

CALIFA Barrel

- Long CsI(Tl) (up to 22cm long) readout with LAAPD (10x20 mm)
- Energy resolutions for this geometry (~ 5% at 1 MeV γ)
- Good resolutions for fully stop protons (up to 320 MeV)



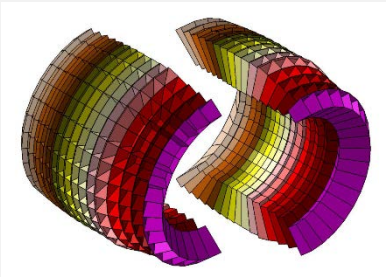




- R&D period: 2005-2011
- TDR approved January 2013
- Construction starts in 2013 DEMONSTRATOR Phase (20% of the Final detector)

Institutions
USC (Spain)
IEM (Spain)
Uvigo (Spain)
ULund (Sweden)
TU Darmstadt (Germany)
TU Munich (Germany)

CALIFA Barrel

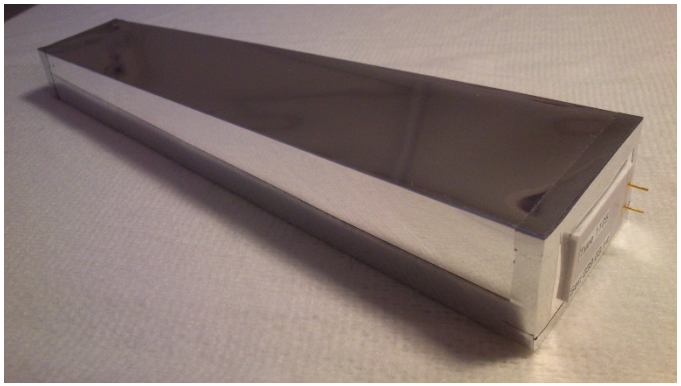


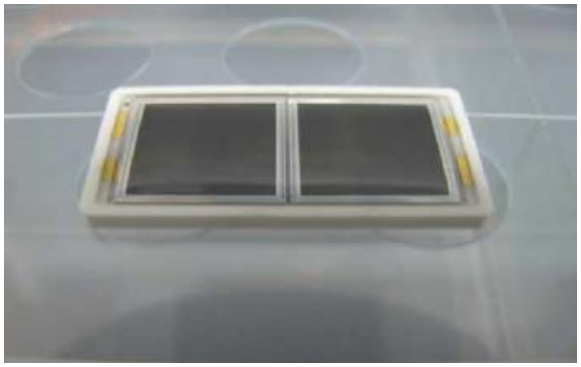
Inner radius	30cm
N of crystals	1952
Crystal geometries	11
Crystal volume/weight	285000cm^3 / 1300kg

Technical specifications fixed

Purchase of the elements to built the CALIFA first stage initiated in 2013. Construction in progress(DEMONSTRATOR)

Long CsI(Tl) crystals + Large Area Avalanche Photodiodes (LAAPD)





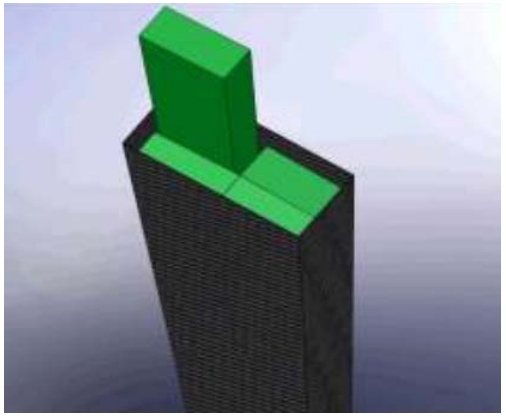
AMCRYS

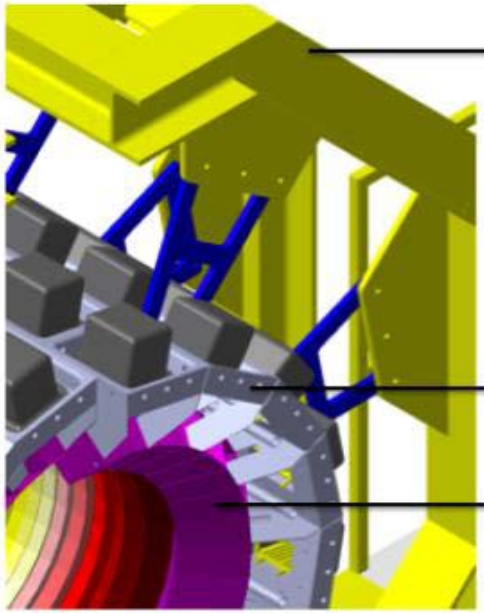
HAMAMATSU
S8664-1010-2CH

CALIFA Barrel Mechanics

Individual crystals grouped by4 in the Carbon Fiber based mechanical structure 'alveolus‘ 300um thickness

Alveolis grouped by 8 to share one cover 'tile', which serves as interface





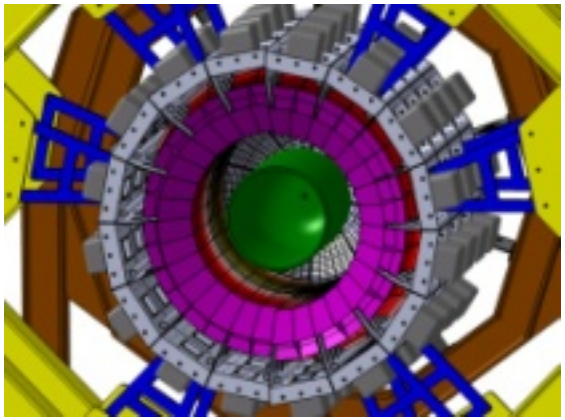
External structure: gantry

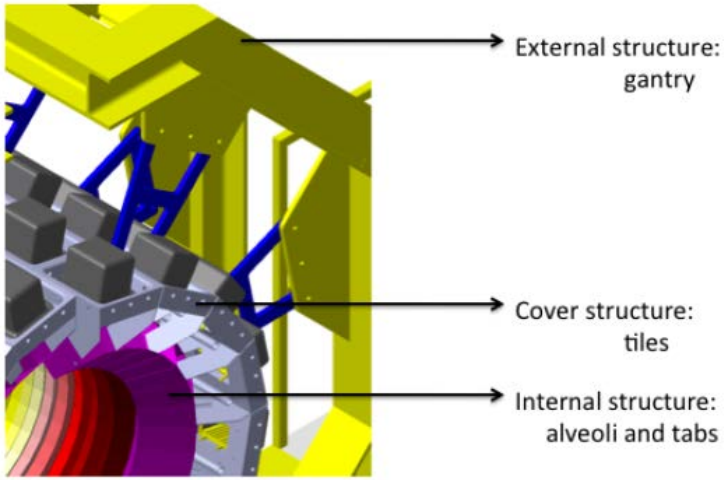
Cover structure: tiles

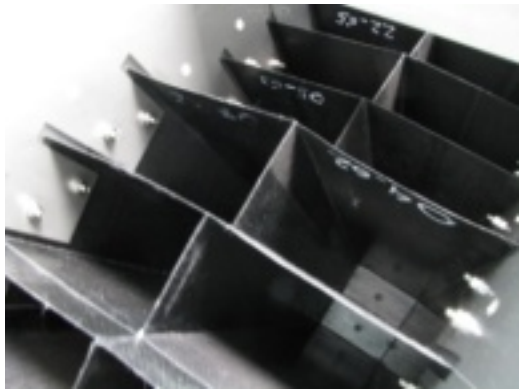
Internal structure: alveoli and tabs

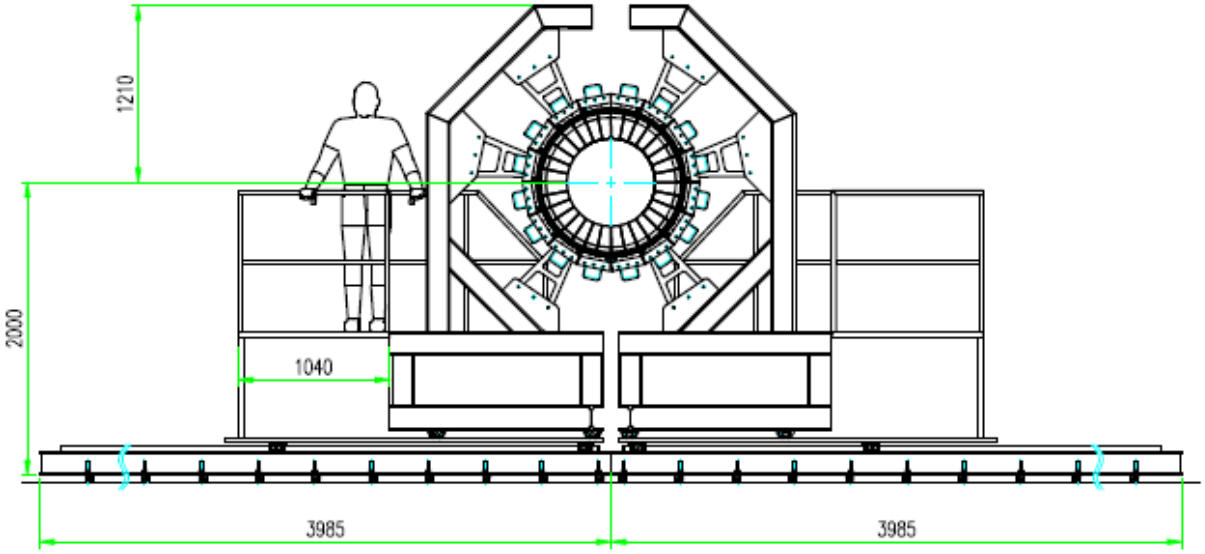
CALIFA Mechanical Structure

Implementation in three layers









CALIFA readout concept

Based on 3 independet layers combining analogue and digital solutions

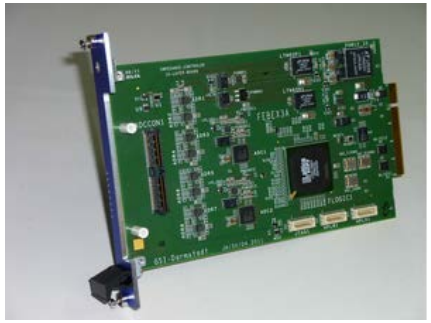
✓**Preamplification** : mounted directly at the detector (optimized for low noise and low power consumption and simple mechanical access)

✓**Digitizers** modules located on the movable support of the detector. They perform full signal processing and provide buffer memory for an asynchronoues data collection.

✓**DAQ** electronics based on MBS and GOSIP protocol.

Mesytec MPRB-32

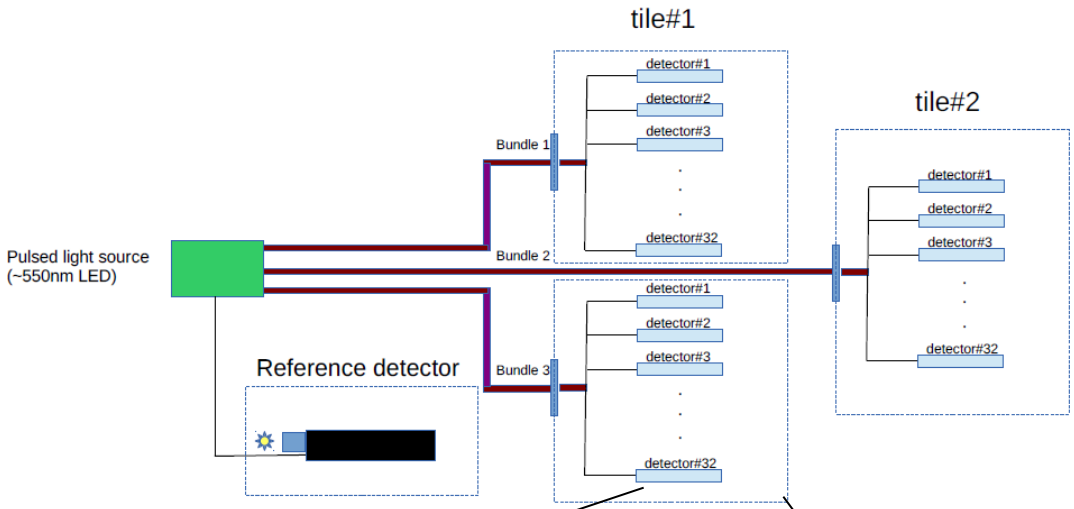
- 2x 16 channel charge-sensitive preamp (dual range 3/30 pC)
- Individual voltages up to 600V
- Gain stabilization
- Remote control



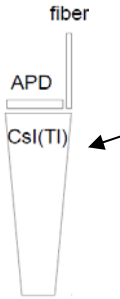
FEBEX3

- 16 channel pipeline ADC Front End Board with optical link EXtension.
- ADC sampling rate 65 Ms/s, resolution is 12 bit.
- Trigger logic, time stamp logic and external clock input to high precision PLL synthesizer.

CALIFA Barrel gain monitoring



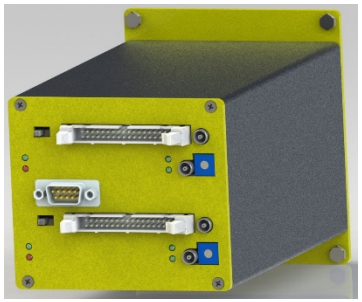
first prototype developed with Mitsubishi

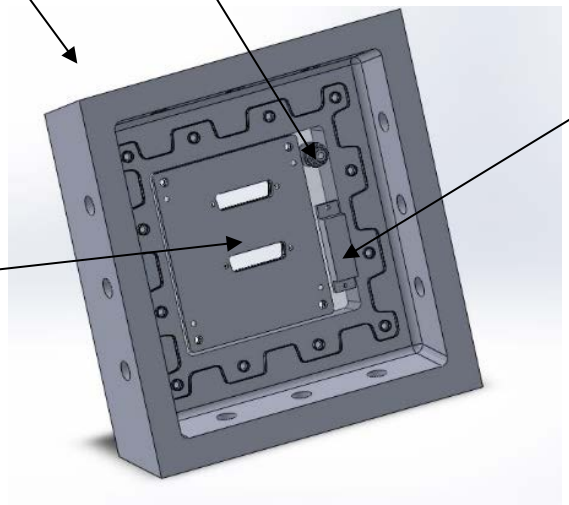


gas inlet

optical fiber connector

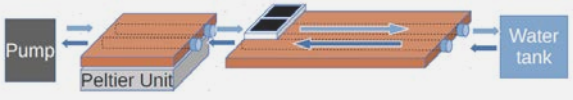
32ch preamp

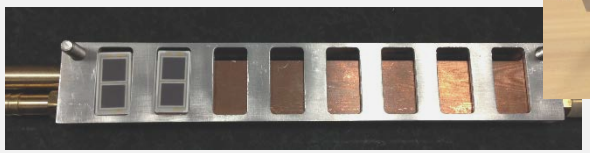




Quality assurance and characterization of APDs

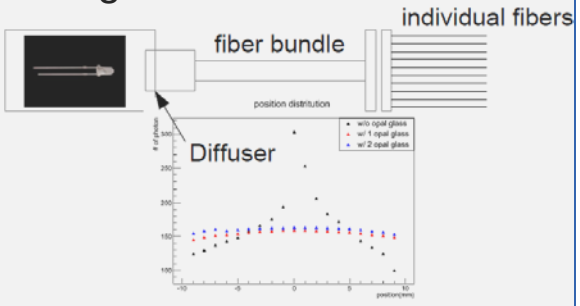
APD test stand for temperature controlled measurements





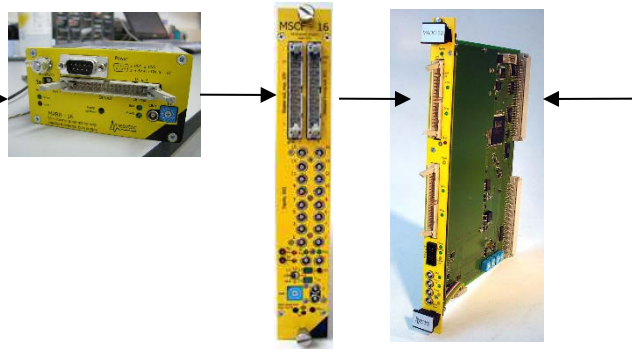
- 8 double APD units
- Peltier element with circulating liquid
- LED light source
- Temp. range 15 – 25 C
- Temp. controller + sensor accuracy 0.01C

LED light source with diffuser



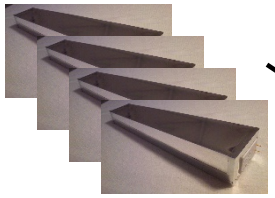
- Nichia green LED (525nm)
- Diffusing glass
- 2 fibers per double APD

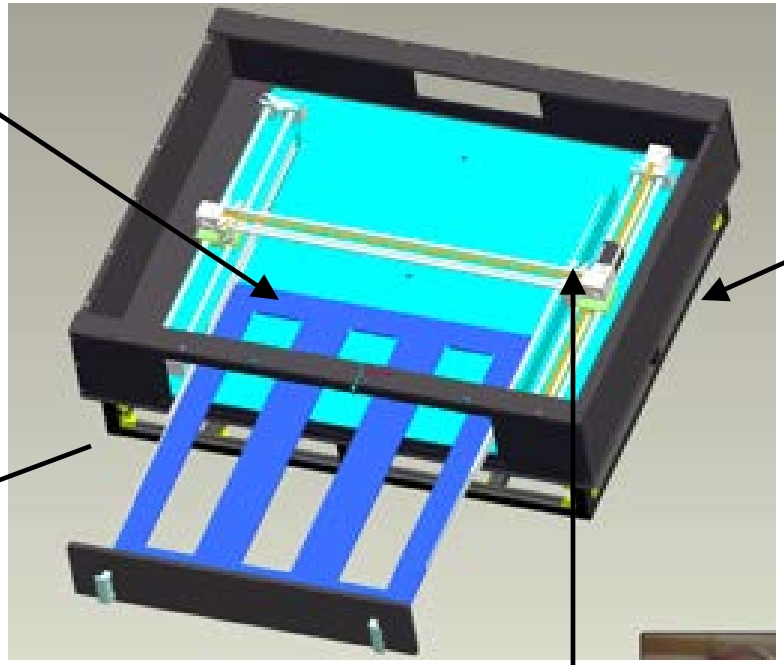
Analogue readout
MPRB preamp + MSCF shaping amp + MADC

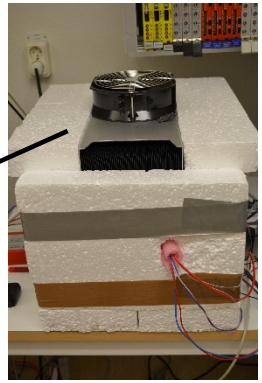


NTC thermistor interface

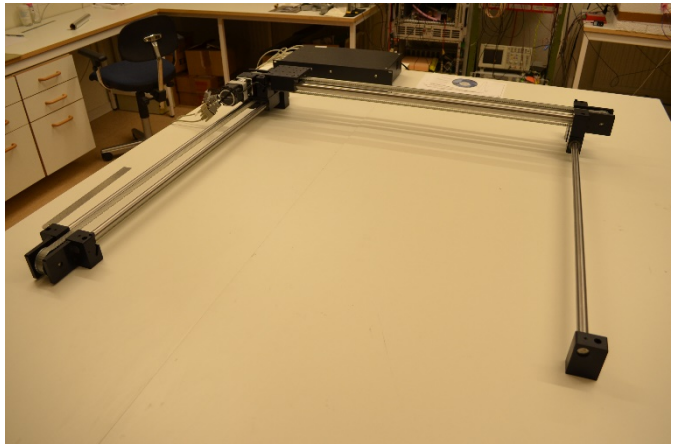
CALIFA crystal testing station @LU-DetLab





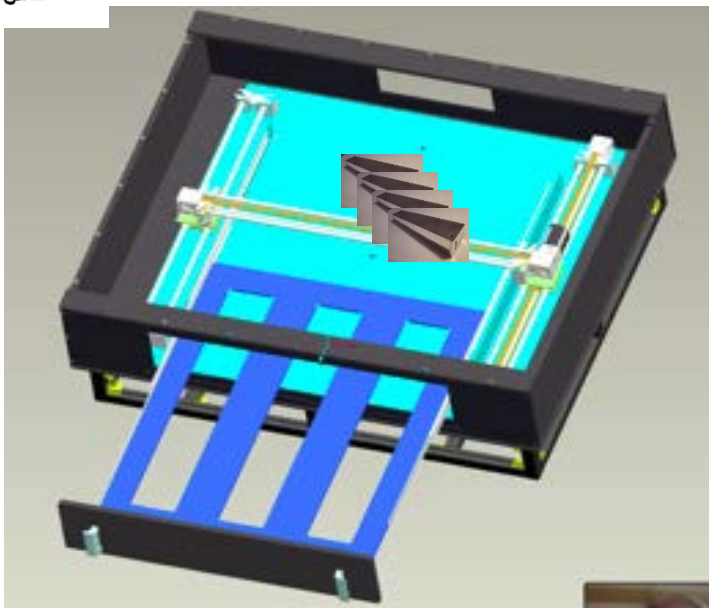


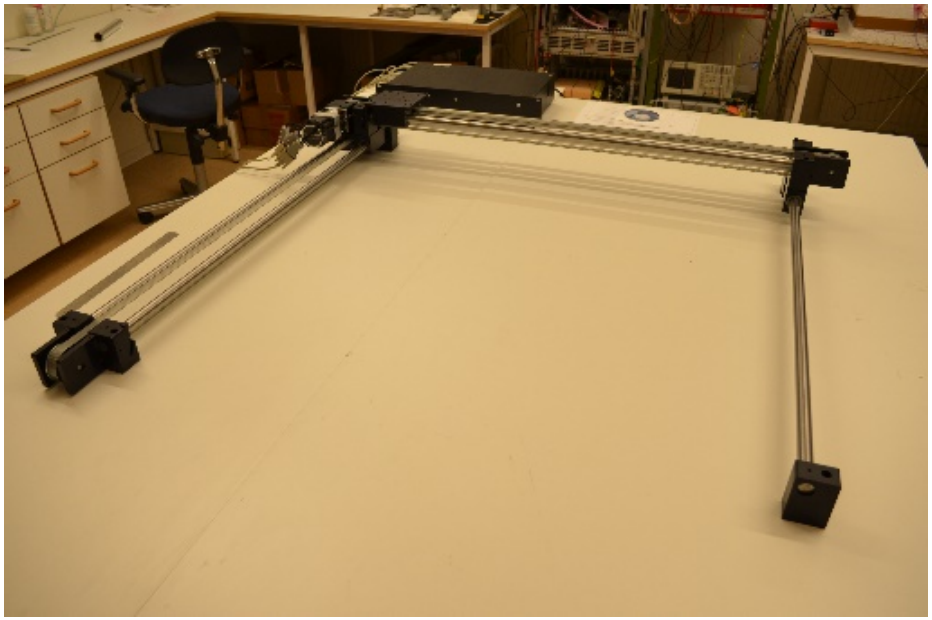
DAQ, MBS



- Desiccator Cabinets
- Climate control
- Humidity control, RH ~ 4-5%
- UV protected
- P_2O_5 desiccant (phosphorus pentoxide)

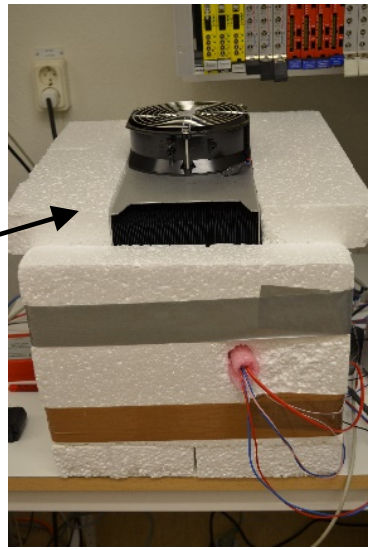
CALIFA crystal testing station @LU-DetLab





Climate chamber with XY table

- Up to 32 CsI can be mounted
- Integrated standard CALIFA preamp
- All types of CALIFA CsI
- Thermo isolated
- Temperature controlled by Peltier element
- Thermo stabilization prototype tested, acc. 0.1°C, PID controller
- Temperature response scanning
- Thermo ramp up/down for stability testing (glue, optical contact)



Linear Positioner: XY table

•Provides great stiffness and repeatability

•Can hold few collimated ɣ-sources for faster scanning

•ASCII code controllable, integrated into DAQ

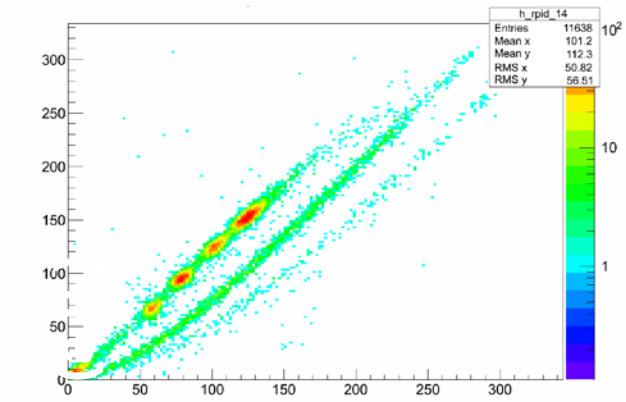
•Low power motors → compatible with climate chamber

•Tested (master student project)

CALIFA ENDCAP

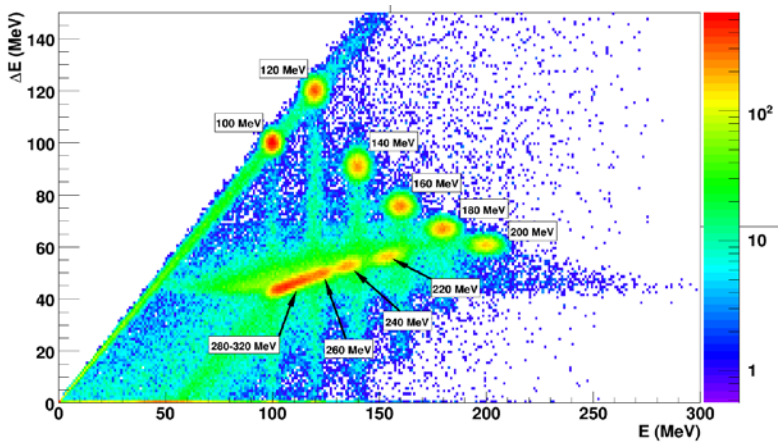
iPhos

- ✓ CsI(Tl) (18-20 cm long) readout with LAAPD
- ✓ Two time decay constants (~ 600 ns and 3.5 μs) →the related scintillation amplitudes can be used for particle identification.
- ✓ p Energy determination up to 700 MeV (ΔE/E ~ 5%)



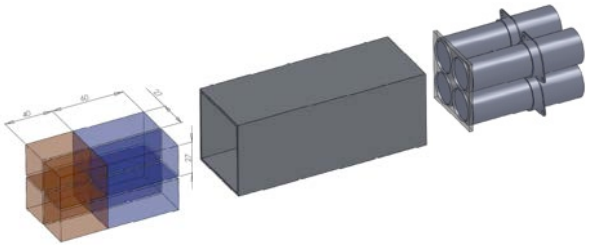
CEPA

- ✓ Phoswich of 4cm LaBr +6cm LaCl
- ✓ 1MeV γ ΔE/E ~ 3% , punch trough p ~ 5%
- ✓ Good timing

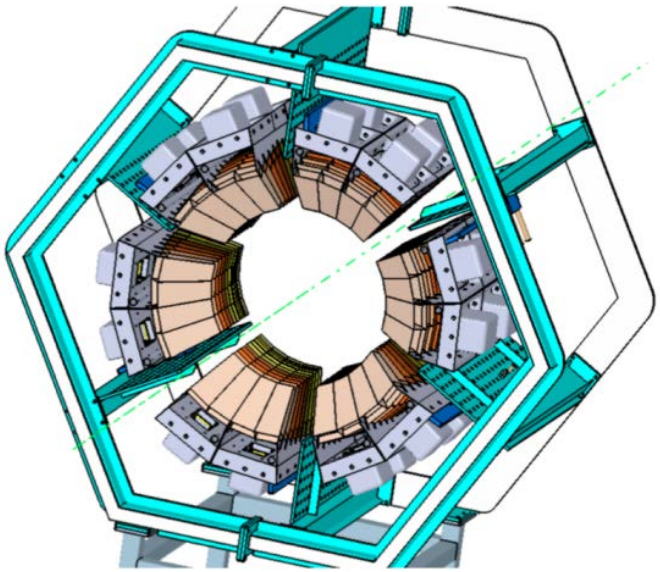


Institution	Funds
Chalmers (Sweden)	475 k€
Germany	request 2014
Spain	request 2015

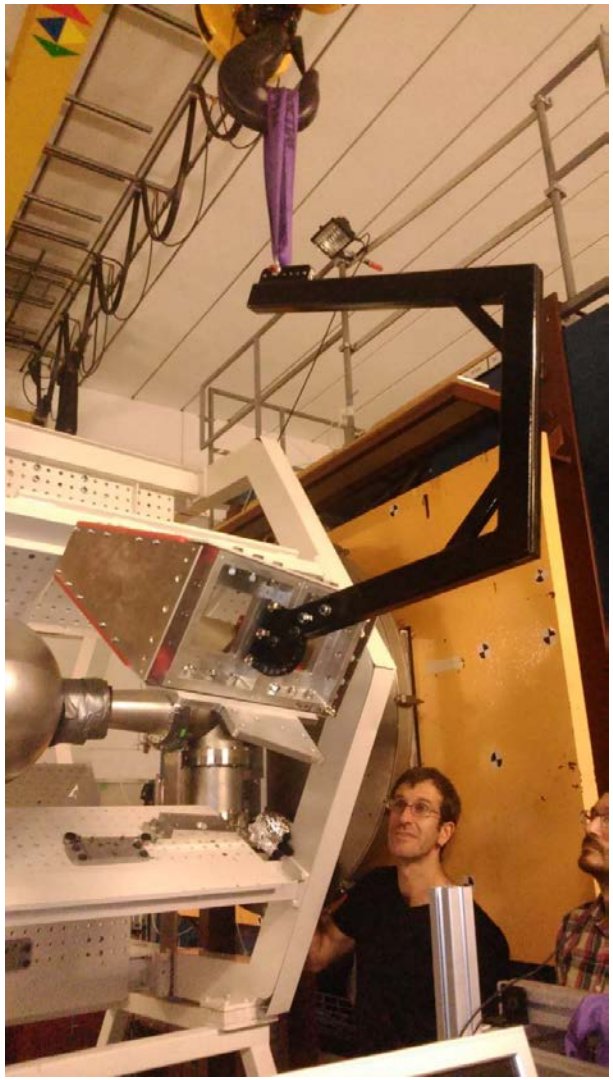
- ➢ R&D period 2005-2014
- ➢ TDR t.b. submitted Nov. 2014



CALIFA Demonstrator tests



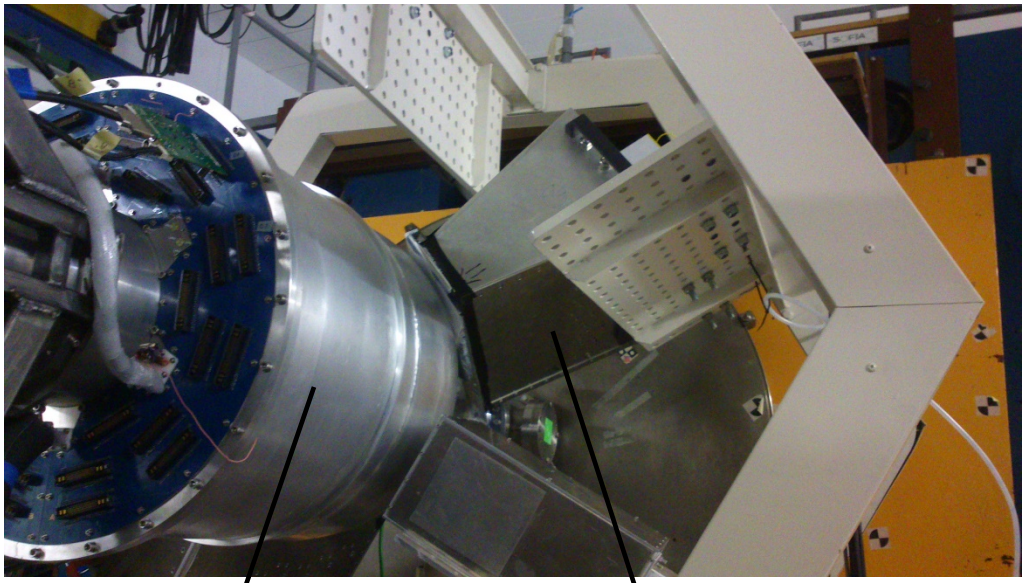
- Dedicated structure
- Up to 12 Petals
- Petal = (8x2 carbon fiber alveoli= 16x4 = 64 detection units CsI(Tl) / APD + FEE)
- Funded by Spain, Sweden and Germany

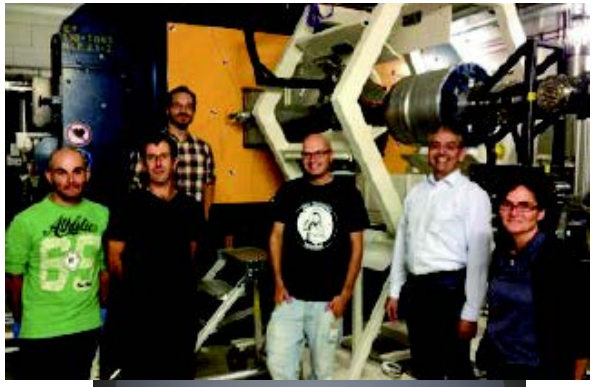


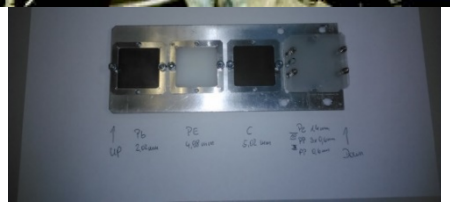
- Prototype test at MLL, Upssala, CMAM, TUDarmstadt
- Petal tests at IFJ PAN
- Demonstrator tests at GSI
  2 PETALS

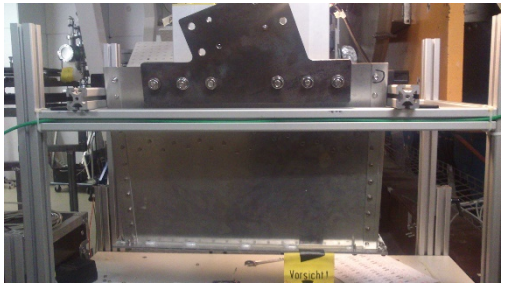
CALIFA Demonstrator tests

1-8 October 2014 at Cave C. First coupling test for Si-Tracker, CALIFA +NeuLAND







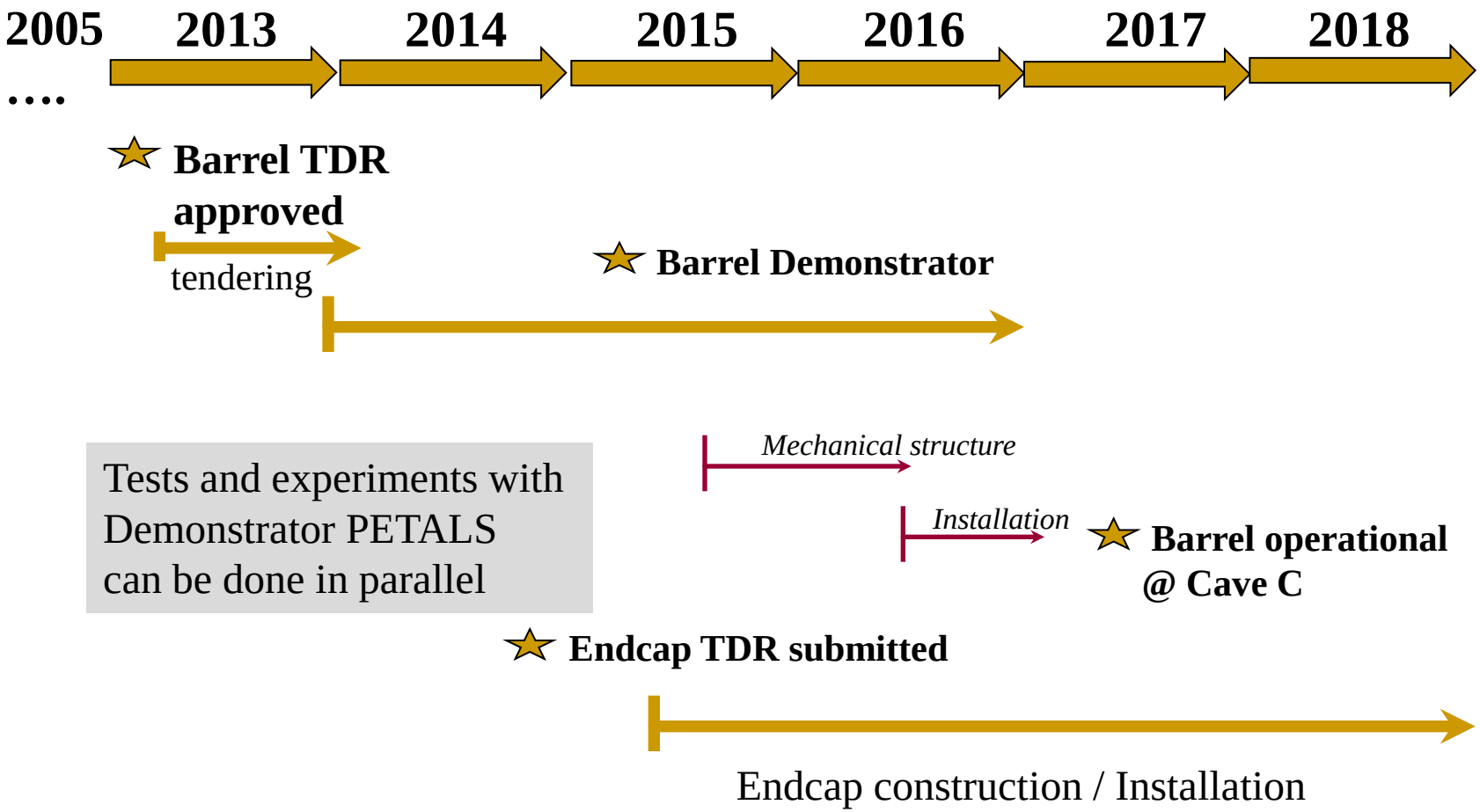


- ^{48}Ca + PE → (p,2p) reaction
  test of the Hybrid mode
  γ spectroscopy and p calorimetry

- ^{48}Ca+ C → neutron knoctout
  γ spectroscopy of ^{47}Ca

- ^{48}Ca+ Pb → PDR excitations
  γ cascade (γ calorimetry)

CALIFA Time Schedule



Tests and experiments with Demonstrator PETALS can be done in parallel

SFAIR CALIFA Funding

		Costs [k€]	Inst.	FAIR/ext	-2014	2015	2016	2017	2018
		2,800							
1.2.1	LEB Super-FRS								
1.2.2	HISPEC/DESPEC	1,000							
1.2.2.2.2	HISPEC/DESPEC Beamline (2nd share)	20.0	Lund	FAIR				20.0	
1.2.2.2.9	HISPEC/DESPEC Beamline (9th share)	20.0	Lund	ext				20.0	
1.2.2.10.2	LYCCA (2nd share)	150.0	Lund	FAIR	150.0				
1.2.2.10.4	LYCCA (4th share)	100.0	Lund	ext	100.0				
1.2.2.14.8	DESPEC high-res. g-detector (8th share)	400.0	KTH	FAIR				400.0	
1.2.2.14.10	DESPEC high-res. g-detector (10th share)	250.0	KTH	ext				250.0	
1.2.2.16.3.1	NEDA (1st share)	30.0	Uppsala	FAIR		30.0			
1.2.2.16.3.2	NEDA (2nd share)	30.0	Uppsala	ext		30.0			
1.2.5	R3B	1,800							
1.2.5.1.1.1.1	Quadrupole triplet (1st share)	75.0	VR-RFI	FAIR			75.0		
1.2.5.1.1.1.3	Quadrupole triplet (3rd share)	75.0	VR-RFI	ext			75.0		
1.2.5.1.2.3.1.1.	CALIFA barrel stage 1 (5th share)	399.2	Lund	FAIR	399.2				
1.2.5.1.2.3.2.6	CALIFA forward endcap (1st share)	251.0	Chalmers	FAIR			250.8		
1.2.5.1.2.3.2.3	CALIFA forward endcap (3rd share)	600.0	Chalmers	ext			600.0		
1.2.5.1.3.3	Vacuum systems (3rd share)	20.0	Lund	FAIR				20.0	
1.2.5.1.3.4	Vacuum systems (4th share)	20.0	Lund	ext				20.0	
1.2.5.1.4.2	DAQ electronics (2nd share)	140.0	Chalmers	FAIR					140.0
1.2.5.1.4.4	DAQ electronics (4th share)	110.0	Lund	ext					110.0
1.2.5.1.5.2	Gas supplies for detectors	20.0	Lund	FAIR				20.0	
1.2.5.1.5.3	rack cooling system	20.0	Lund	FAIR					20.0
1.2.5.1.5.4	fire safety for electronic racks	20.0	Lund	ext					20.0
1.2.5.1.5.5	long cables and trays	50.0	Chalmers	FAIR				50.0	
	Total NUSTAR				649.2	60	1001	800	290

Sum FAIR in-kind	1,575
Sum external	1,225
LEB Building	350
SUM NUSTAR	3,150