Front-end electronics based on an autonomous, trigger-less ASIC for LHAASO

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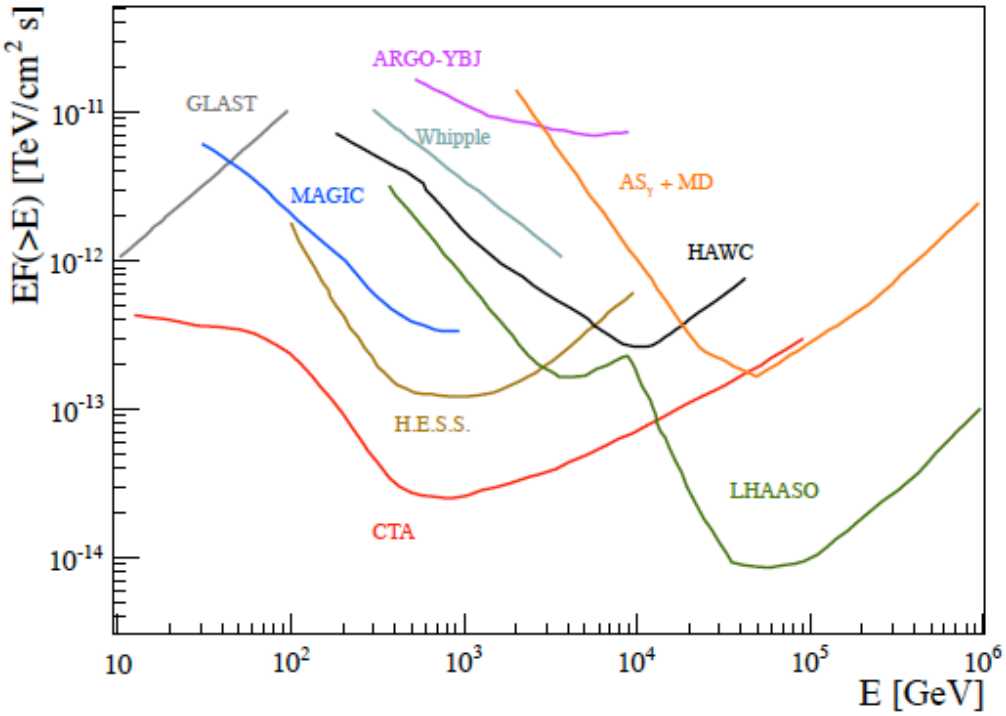
Outline

- Science case, site and layout of LHAASO
- Challenges for electronics
- Adaptation of PARISROC 2 for the front-end electronics of WFCTA
- PMTs
- Collaboration, actions and funding

Science case for LHAASO

- Survey of the gamma sky above 100 GeV
  - **Wide FOV and high duty cycle**
    - Observations of large number of sources
    - Observation of transient and extended sources
- Search for cosmic-ray origin among galactic gamma-ray sources
  - **Gamma spectra at high energies (above 100 TeV)**
    - Visibility for hadronic origin and charged particle acceleration
- Measurement of cosmic rays above 30 TeV
  - Bridge between direct and indirect measurements
  - Unprecedented statistics for anisotropy studies in the knee region
  - Accurate measurement of primary composition



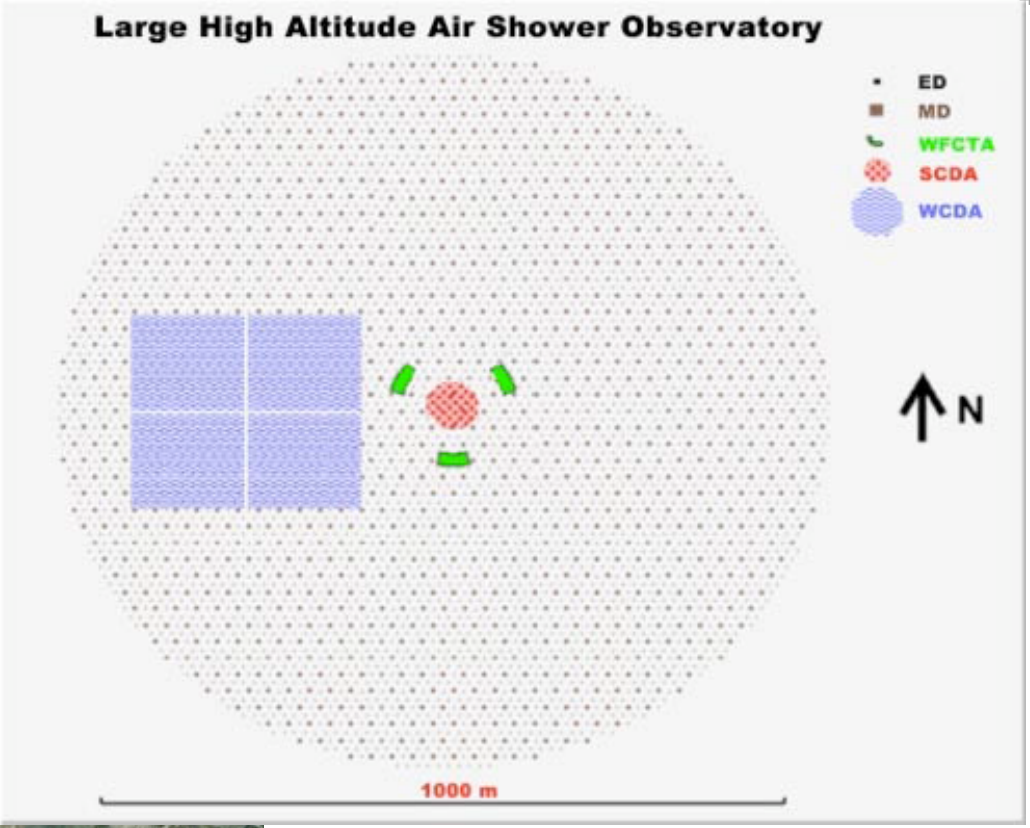
Site and layout

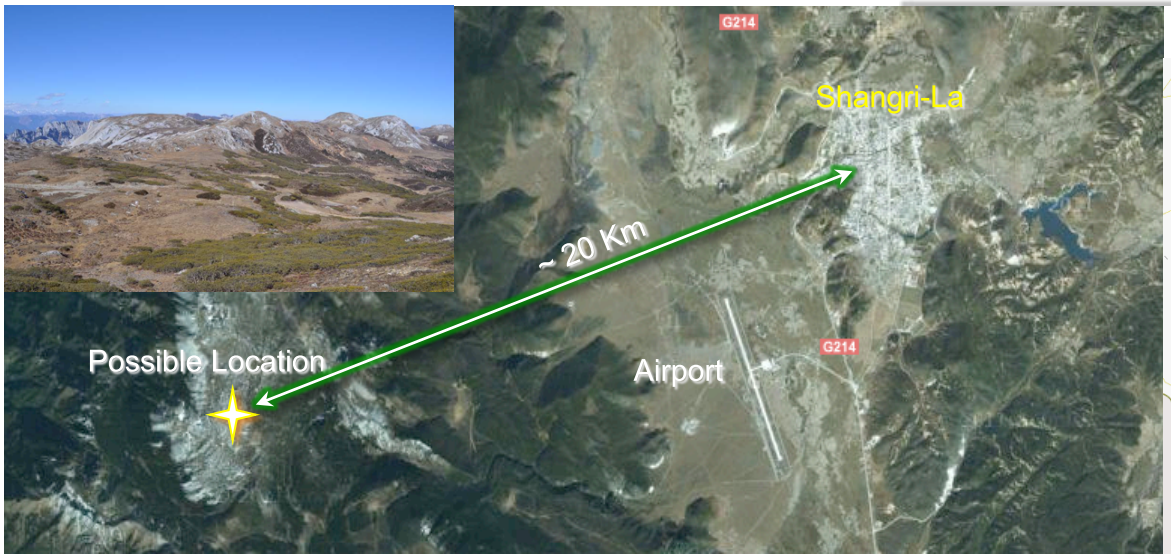
Site

- *~ 4300 m a.s.l., Shangri-La, Yunnan, China*

Detectors

- *KM2A, WCDA, WFCTA, SCDA*



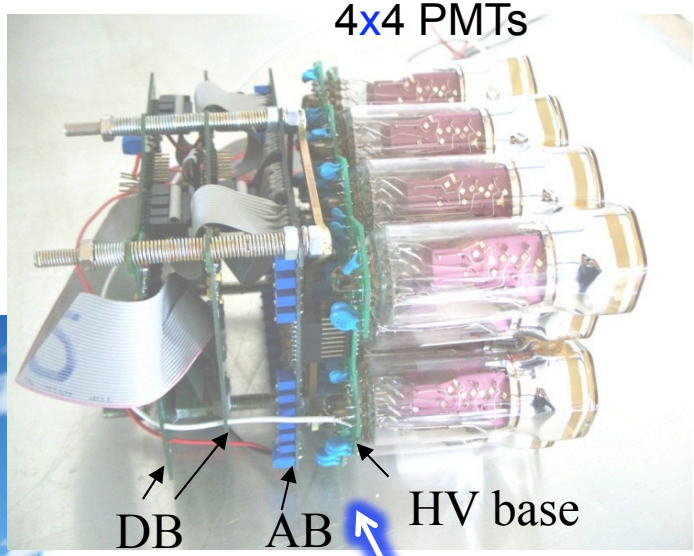


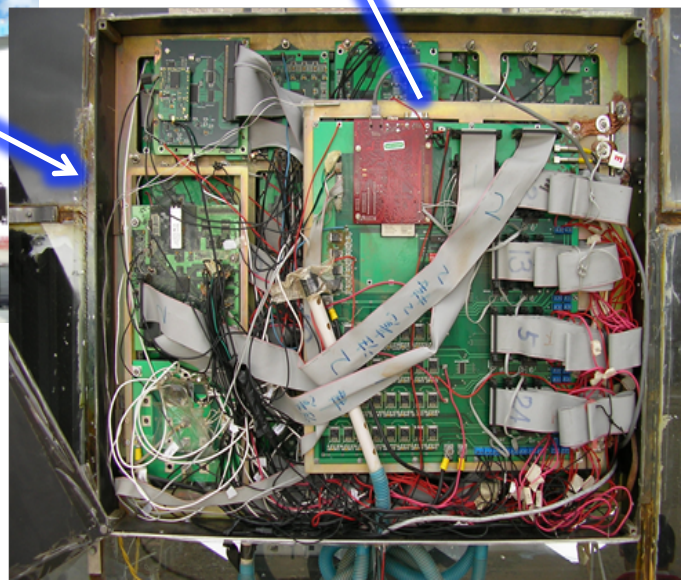
Challenges for electronics

- Different requirements -> Different electronics
- High altitude -> Low heat dissipation
- Large number of channels -> complexity of electronics

- Compact design
- High stability
- High reliability
- Low power dissipation
- Easy to maintain

Focus on WFCTA at first.





Prototypes in YBJ, Tibet

The ASICs can be used to simplify the electronics.

PARISROC 2

Technology: 0.35µm SiGe AMS

Photomultiplier **AR**ray **I**ntegrated in **S**iGe **R**eadOut **C**hip

PARISROC 2 is designed by the Orsay OMEGA Group

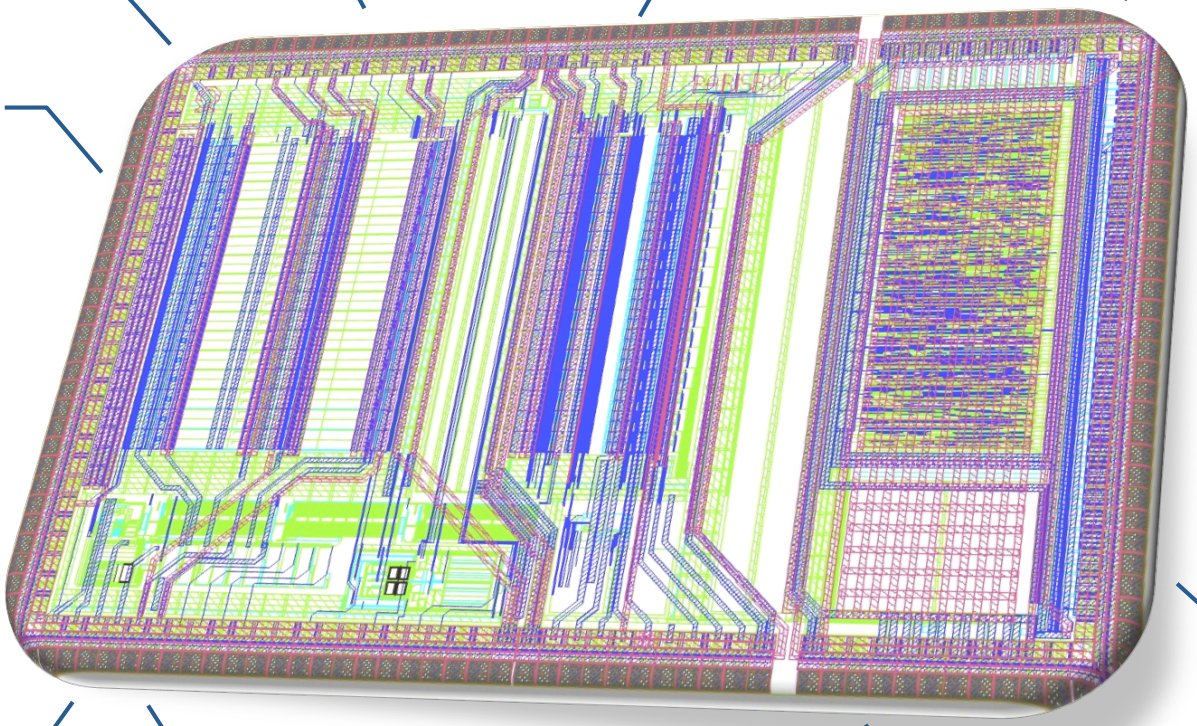
Dual-gain Preamplifiers

Time measurement: tagging < 1 ns

16 Channels (neg.)

10 bit ADC internal conversion

CQFP160 5 mm X 3.4 mm



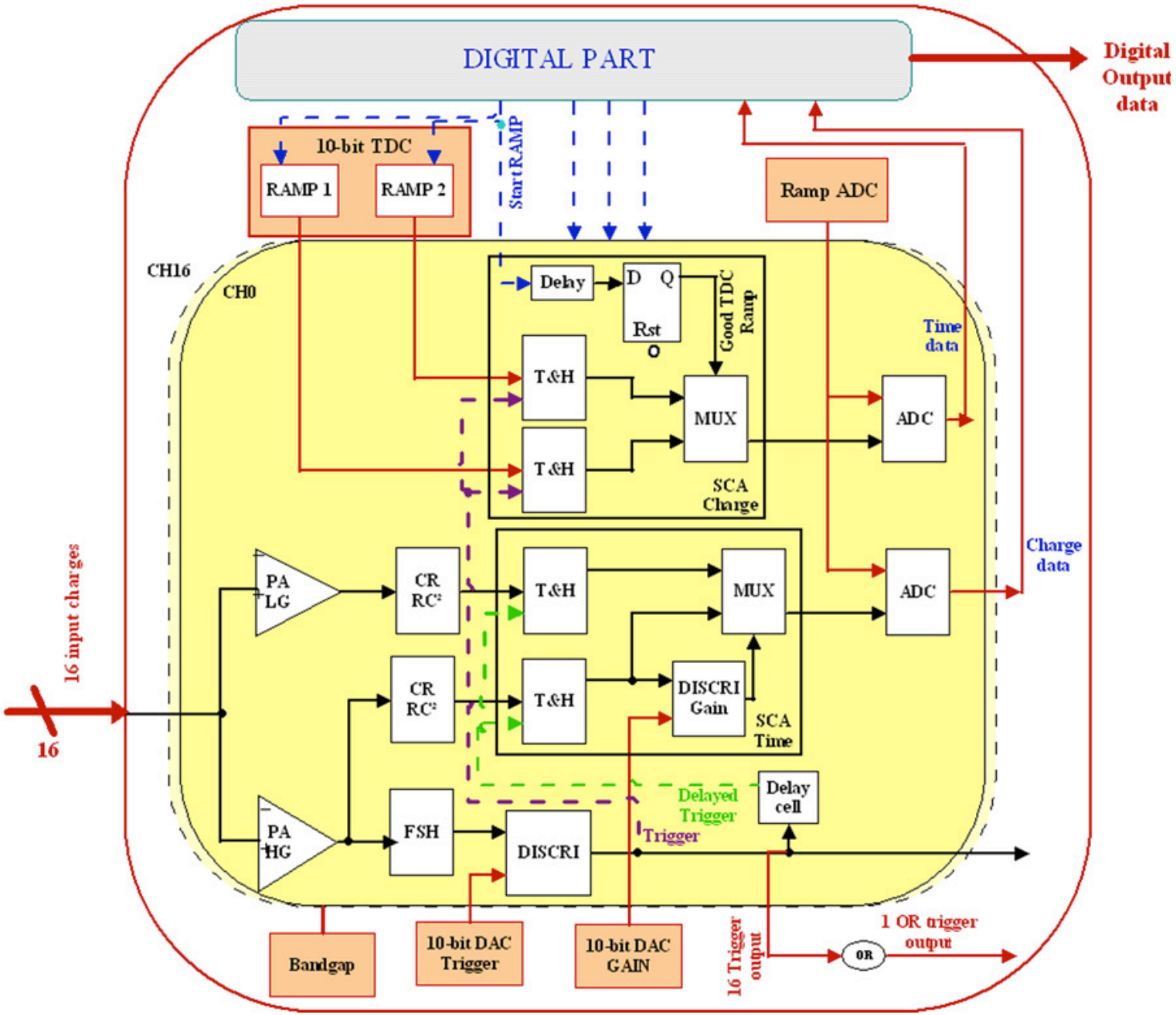
278 slow control parameters

Auto-trigger design

Charge measurement: 50 fC ~ 100 pC

15 mW / channel

Schematics


DIGITAL PART
Digital Output data
10-bit TDC
RAMP 1
RAMP 2
Start RAMP
Ramp ADC
CH16
CH0
Delay
D
Q
Rst
Good TDC Ramp
Time data
T&H
T&H
MUX
ADC
SCA Charge
16 input charges
16
PA LG
CR RC²
T&H
MUX
ADC
Charge data
CR RC²
T&H
DISCRI Gain
SCA Time
PA HG
FSH
DISCRI
Delayed Trigger
Trigger
Delay cell
Bandgap
10-bit DAC Trigger
10-bit DAC GAIN
16 Trigger output
OR
1 OR trigger output

WFCTA

Wide **F**ield of view **C**herenkov/**F**luorescence **T**elescope **A**rray (WFCTA)

Telescopes

- The angular resolution: *< 0.4°*
- The energy resolution: *< 20%*
- The resolution of the location of shower maximum: *< 40 g/cm²*
- The Field of View (FOV) of a single telescope: *14°X 16°*
- Dynamic range: *3 orders of magnitude of the energy*
- Movable design for different purposes
- 24 identical telescopes divided into 3 groups with a distance of 100 m

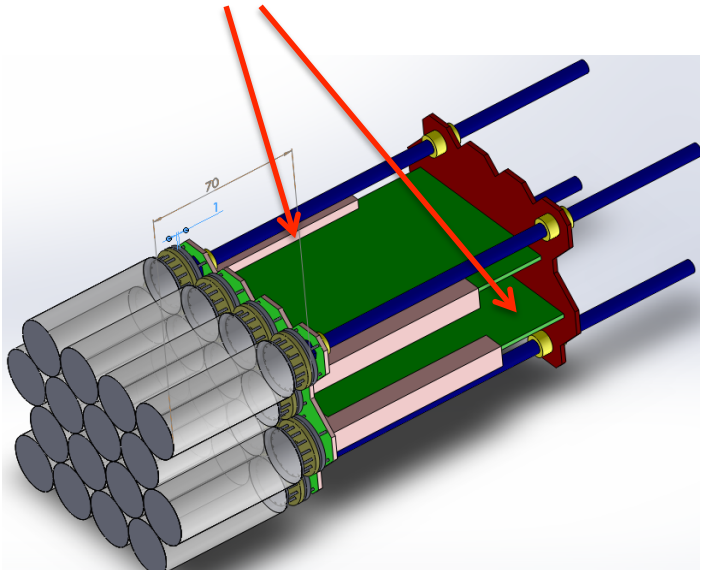
Electronics

- Signal polarity: *Negative (Anode)*
- Dynamic range: *160 fC to 240 pC*
- Nonlinearity: *< 2%*
- Charge resolution: *< 20% @10 pe and <5% @ 15000 pe*
- Time resolution: *20 ns (RMS)*
- Single channel event rate: *10 KHz*
- Signal width: *6 ns to 50 ns (Cherenkov)*
- Pedestal monitoring: *Sky and electronics*
- Channels: *1024 per telescope*
- Power consumption: *260 W*

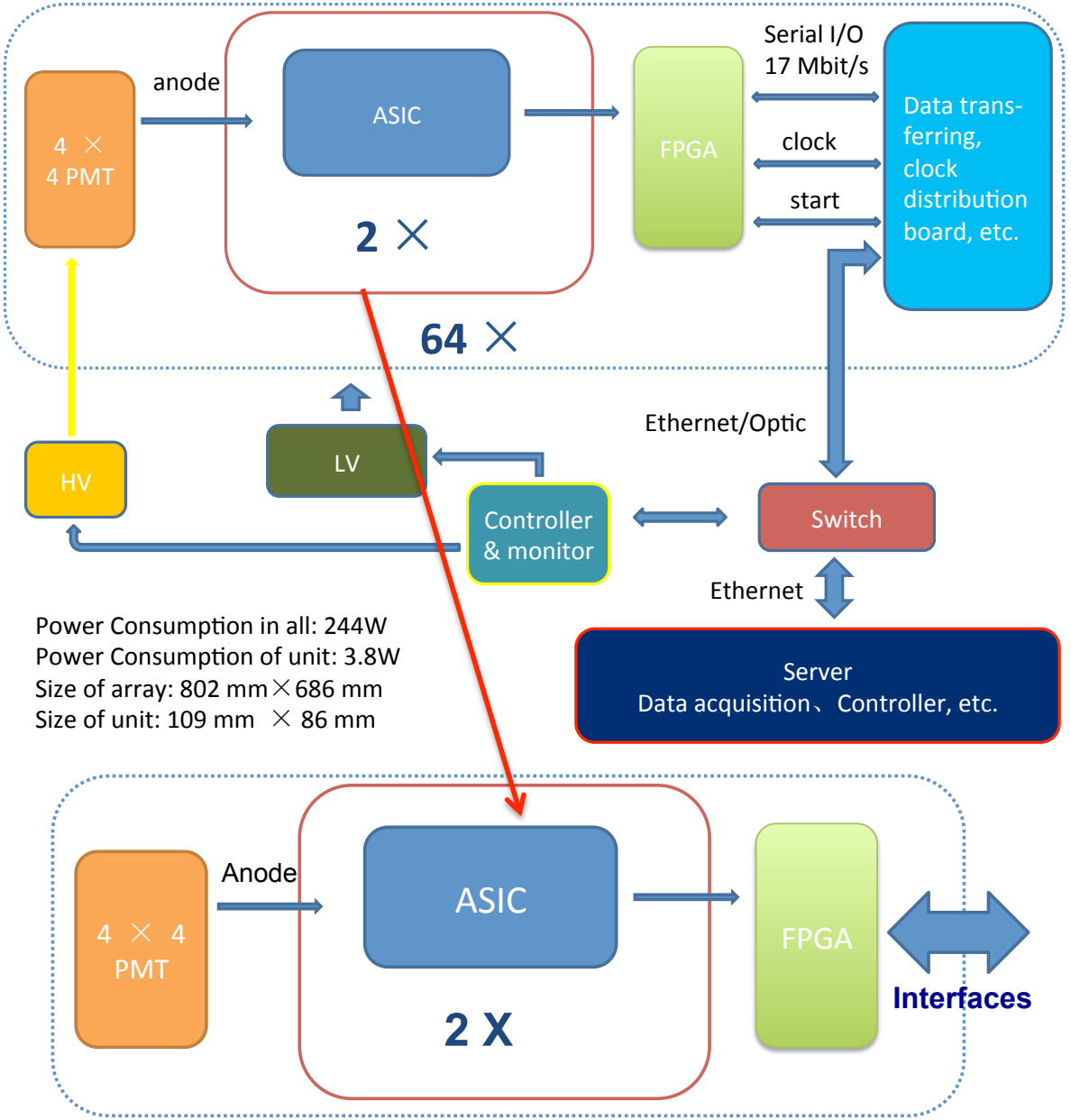
Prototypes in YBJ, Tibet

Schema of WFCTA electronics

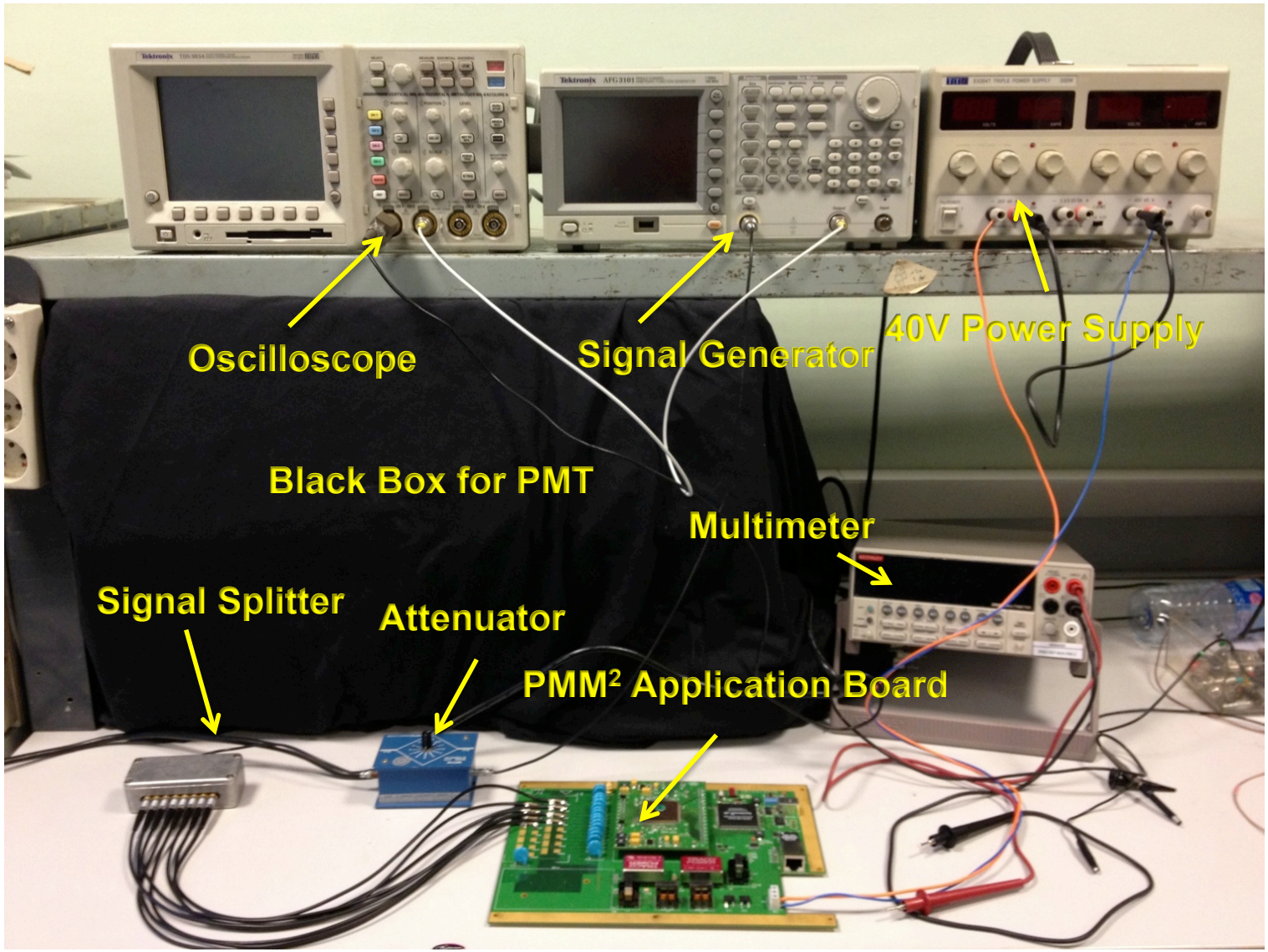
FEE boards



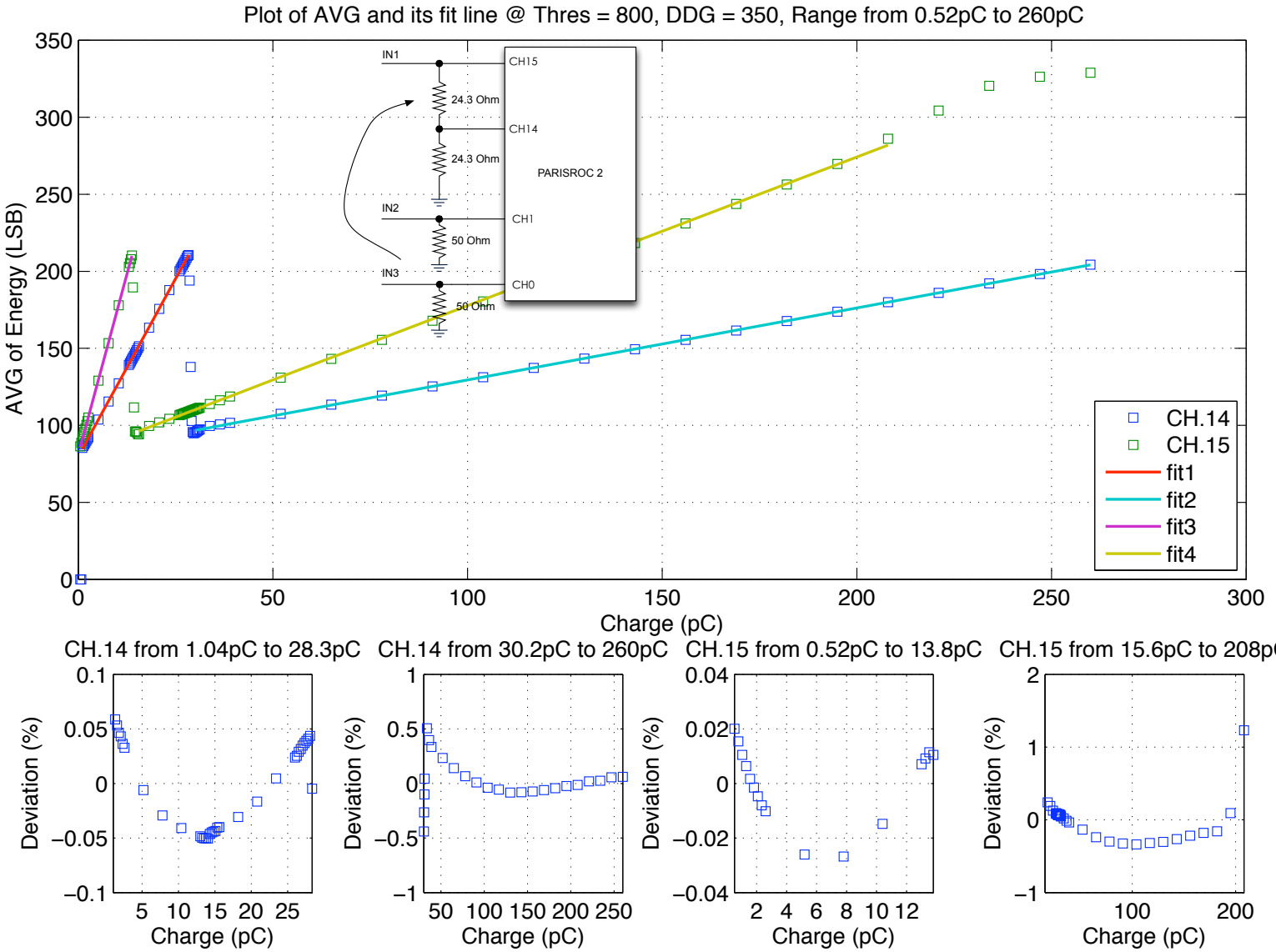
1024 PMT channels per telescope, 16 channels grouped together.



Test bench for PARISROC 2



Test results: Dynamic range



Two channels combined to increase the dynamic range up to 260 pC (spec. 240 pC).

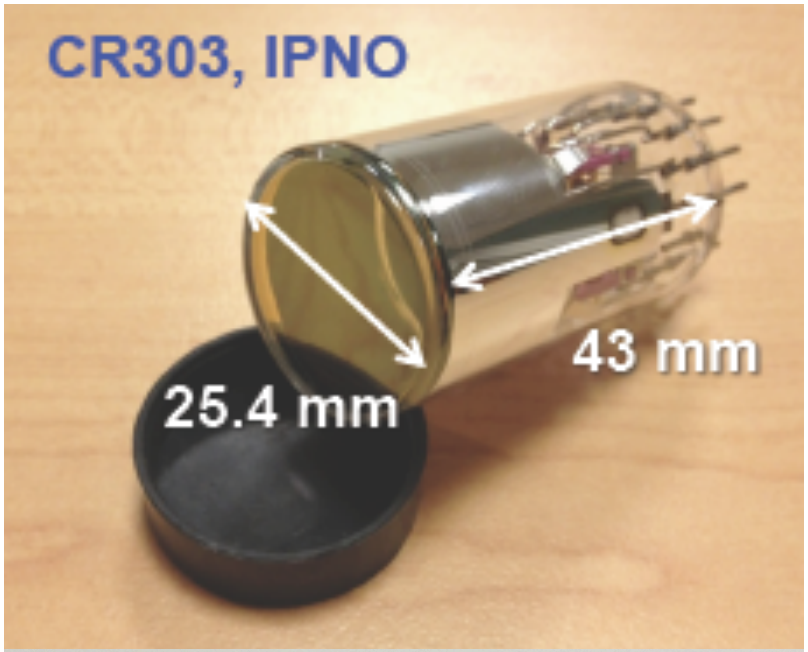
1 mV ≈ 260 fC; 0.6 mV ≈ 1 pe ≈ 160 fC @ PMT Gain 10^6

Test results compared to specifications

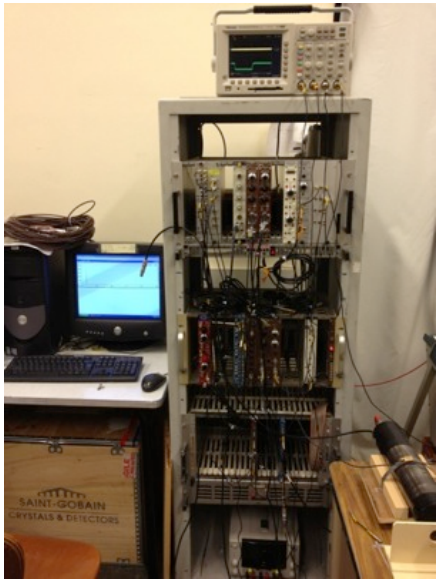
Property	WFCTA Specifications	Satisfied or not
Signal polarity	*Negative (Anode) or Positive (Dynode)*	✔
Dynamic range	*160 fC to 240 pC,　（10pe to 15000pe @ Gain = 10^5 ）*	✔
Resolution	*< 20% @ 10pe and < 5% @ 15000pe*	✔
Nonlinearity	*< 2% or <±1%*	✔
T ime resolution	*20 ns (RMS)*	✔
The adjustable threshold	*5 pe to 100 pe*	✔
Single channel event rate	*10kHz per channel*	Still working on
Width of the signal	*6ns to 50ns (FWHM) for Cherenkov light* *10ns to 3000ns for Fluorescence signal*	✔
Pedestal monitoring	*Background of electronics and sky*	Electronics ✔
Channels	*1024 channels per telescope*	✔
Power consumption	*260W per telescope*	✔

CR303 PMT

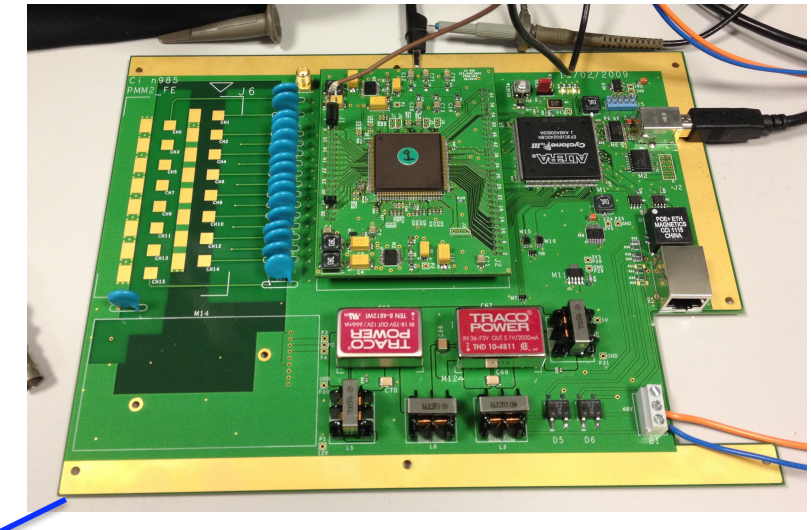
- The CR303 (Hamamatsu Beijing) and R1924A (Hamamatsu) have been chosen as candidate PMTs for WFCTA.
- Base for CR303 designed by IPNO.
- Tests on CR303 performed by using standard electronics and electronics using PARISROC 2.

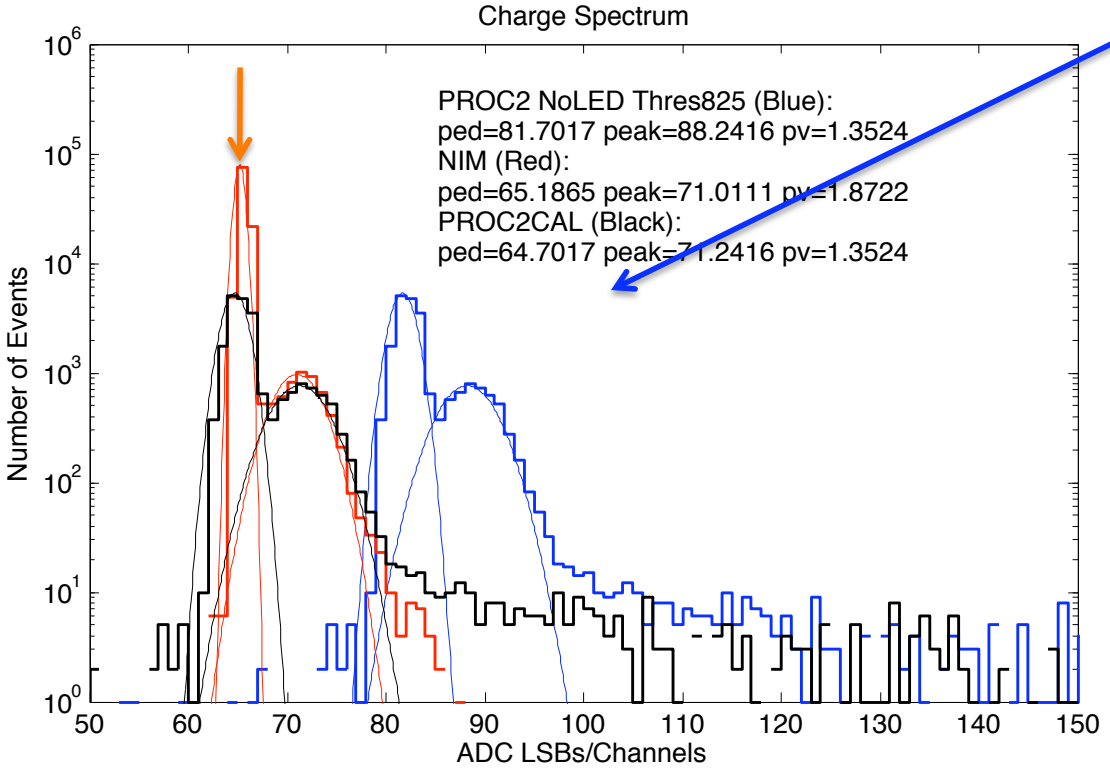


P/V for single photoelectron



LeCroy 2249A:
1024 Channels,
0.25 pC/C.





- The threshold of the PARISROC 2 is the key point for the measurements.
- Measured Peak-to-valley about 1.35.
- Similar results obtained with PARISROC 2 and standard electronics.

Next steps

- Continue PMT testing
- Design and test FEE board for WFCTA
- Adapt PARISROC2 (or another ROC) for other LHAASO detectors?
- Continue simulations on KM2A
- Work on XP1805 9 inch PMT with

This work is important both for LHAASO and Auger.

Inauguration of HZC PHOTONICS

Collaboration

- **Yingtao Chen (PhD student funded by CSC)**, Olivier Deligny, Isabelle Lhenry-Yvon, Tiina Suomijärvi, Francesco Salamida (post-doc), and Diane Martraire (PhD student) from IPN-Orsay.
- The technical group involved in the ASIC R&D: Valérie Chambert, Bengyun Ky, Emmanuel Rauly, Thi Nguyen Trung, Eric Wanlin from IPN-Orsay and Selma Conforti Di Lorenzo, Gisèle Martin-Chassard, Frederic Dulucq, Christophe de la Taille from the Orsay OMEGA group.
- Collaboration with the Chinese LHAASO groups, in particular with the group of Zhen Cao from IHEP.

Actions and funding

- Several visits and regular meetings have been organized.
- **Workshop for Air Shower Detection at High Altitudes** initiated by the LHAASO collaboration, organized at the IPN-Orsay October 2011.
- The financial resources required in the current R&D phase are mainly travel expenses. These expenses have been supported by various agreements, including FCPPL.
- The test bench for the ASIC testing already existed at the IPN-Orsay and was modified for LHAASO R&D with funding from IPN-Orsay.
- Funding requested from FCPPL for 2013:
  - Support the collaboration with LHAASO
  - Support the work on PMTs with HZC PHOTONICS.