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## Construction and characterization of the Central Neutron Detector for CLAS12

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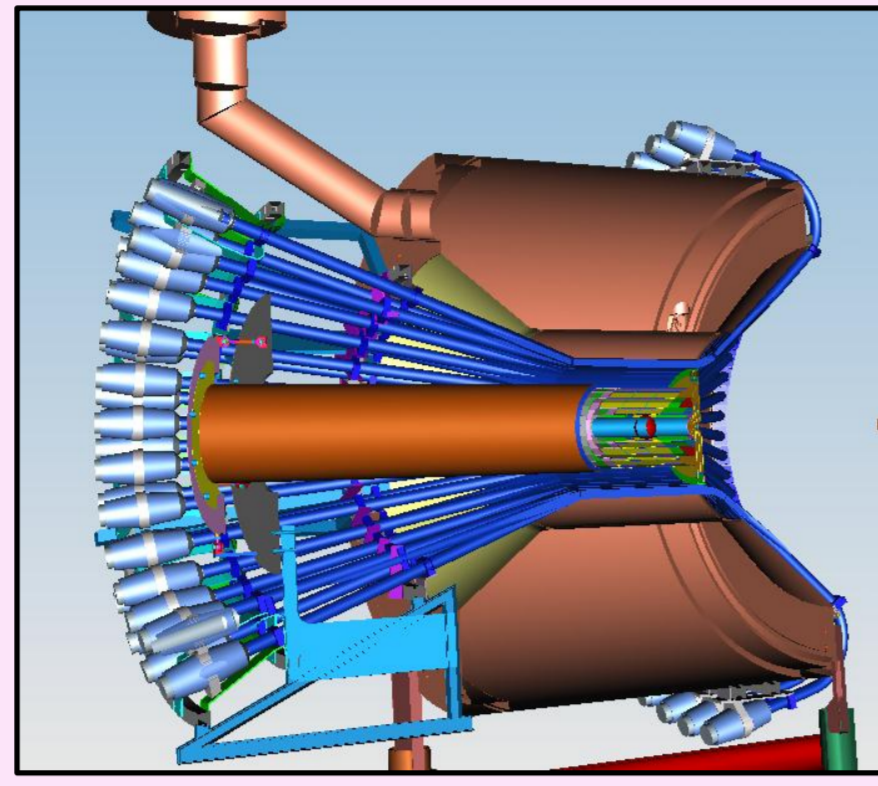
**Introduction:** The CLAS12 experiment at the Thomas Jefferson National Laboratory is focused on the study of nucleon structure and has been conceived to support the energy upgrade to 12 GeV of the Continuous Electron Beam Acceleration Facility (CEBAF). One of the primary interests of the CLAS12 experiment is to measure Deeply Virtual Compton Scattering to study the structure of the nucleon in terms of Generalized Parton Distributions (GPDs). The goal of the nDVCS experiment ( $e d \rightarrow e' n \gamma (p)$ ) is to measure the GPDs of the neutron and gain information on the quark's contribution to the angular momentum of the nucleon.



## The Central Neutron Detector

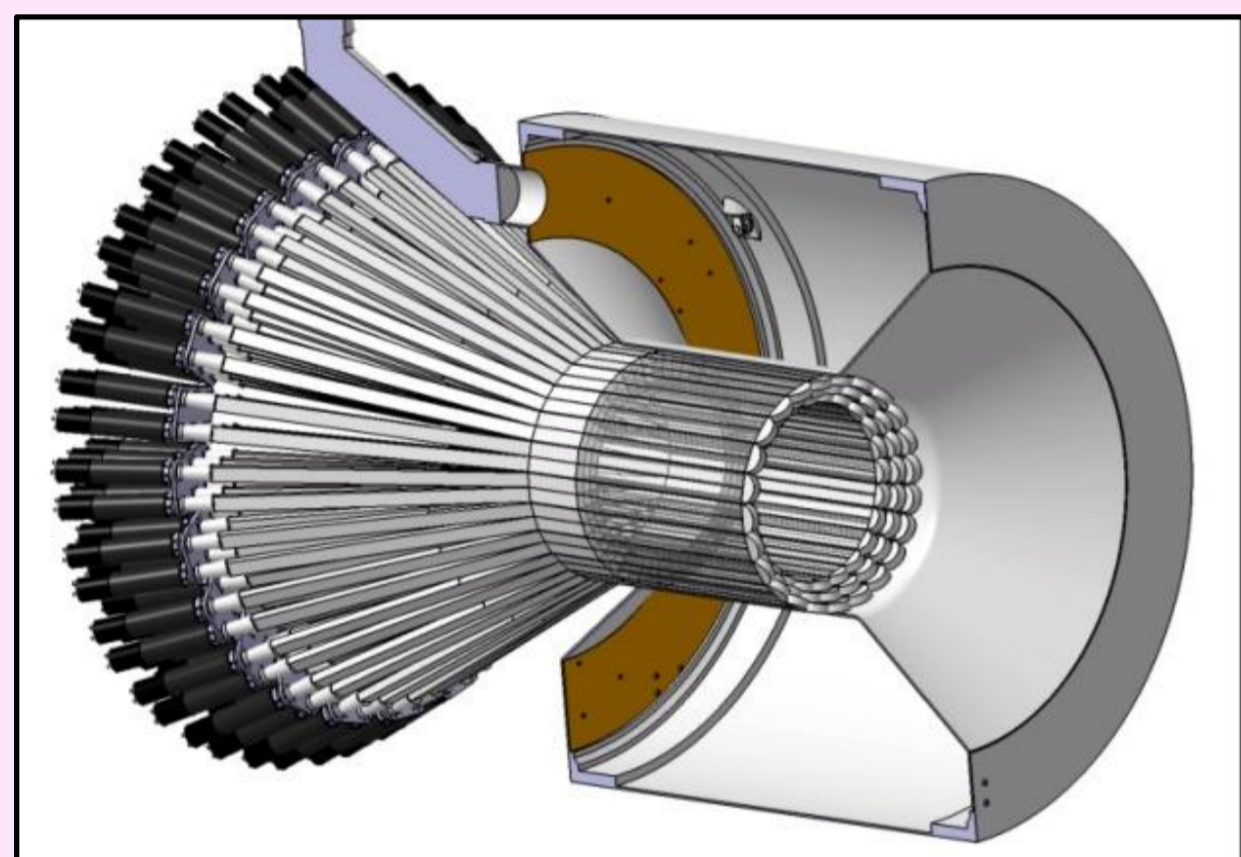
In the nDVCS reaction more than 80% of the neutrons will be emitted at an angle bigger than 40° and so will be localized in the central region of CLAS12

It is crucial to have a dedicated n detector in the central region of the apparatus



The main constrains for the design of the CND are :

- Limited space available (10 cm of total thickness)
- Strong magnetic field (5 T)
- Good time resolution ( $\sigma \sim 150$  ps to ensure n/ $\gamma$  beta separation between 0.2 and 1 GeV)



Three layers barrel of 73, 70 and 66 cm-long scintillators. One end of the scintillator is connected to a long light guide while the other end is glued to a "U-turn" light guide that redirects the light in the neighbor bar. The light is collected on PMTs all placed upstream

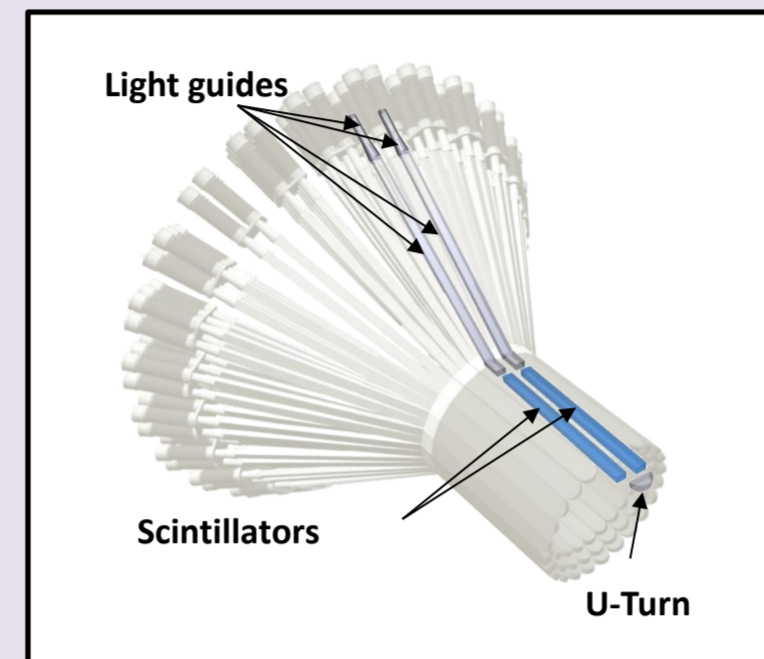
Light yield and time resolution comparative tests to choose the best suited elements for the design of the detector

Shield	PMT	Wrap	Scintillator	Glue	U-turn
2.5 mm	R2083	Mylar Al	BC408	M-BOND 200	Triangular
5 mm	9954A	VM2000	EJ200	BC 600	Semicircular
	R9779	Al foil			
	R10533				

24 blocks of 6 scintillators each, optically coupled two-by-two with a "U-turn" light guide, for a total of 144 scintillators and PMTs

## Detector assembly

The CND construction phase started @ IPNO on December 2013

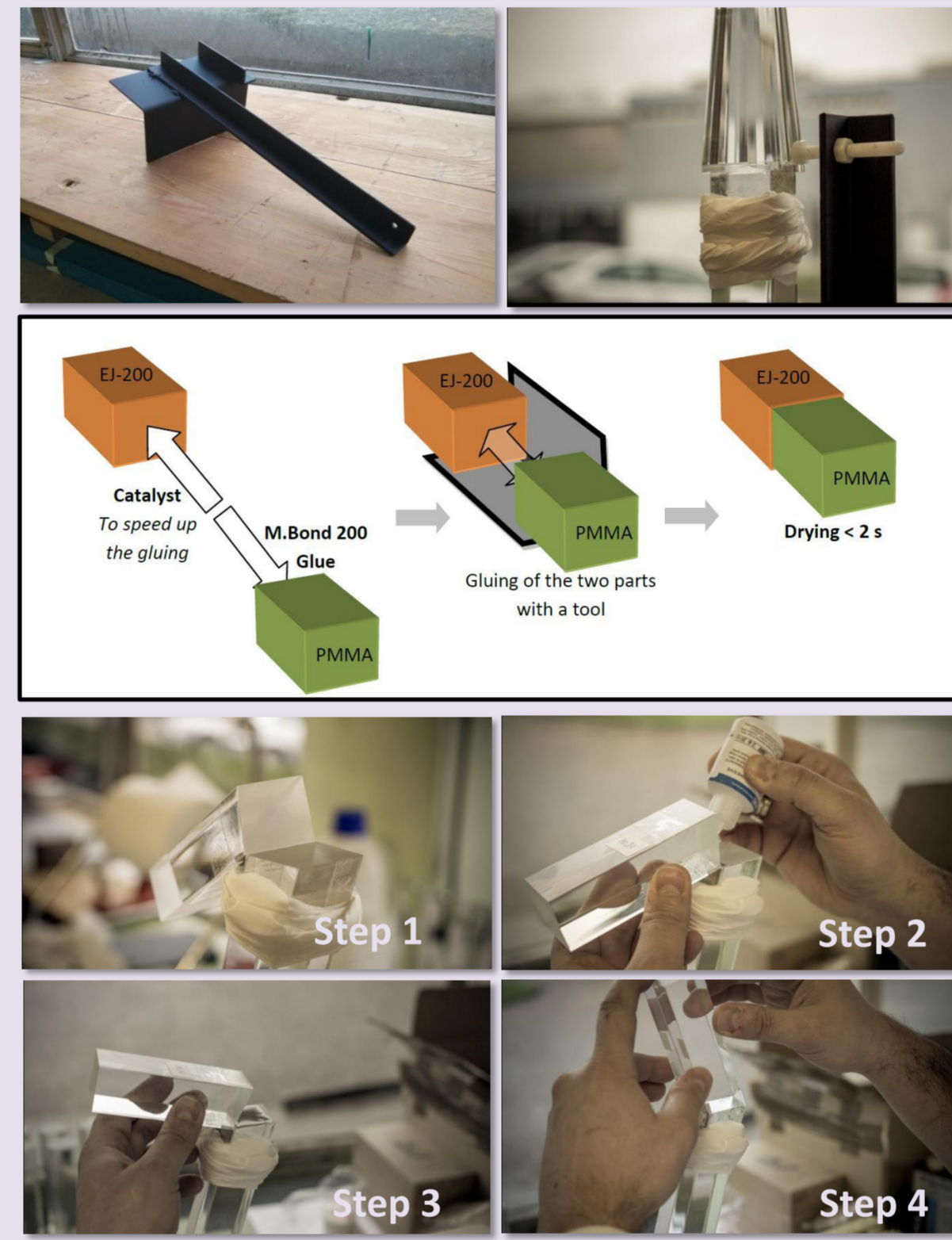


- Operations needed to assemble one block:
- Gluing
    - between fish tail, long and short light guides
    - between light guide and scintillator
    - between two scintillator bars and the U-turn light guide
  - Wrapping
    - with Al foil
    - with black tape
  - Assembling three layers of scintillator couples with foam for correct positioning
- Approximately 1 week of work to assemble one block



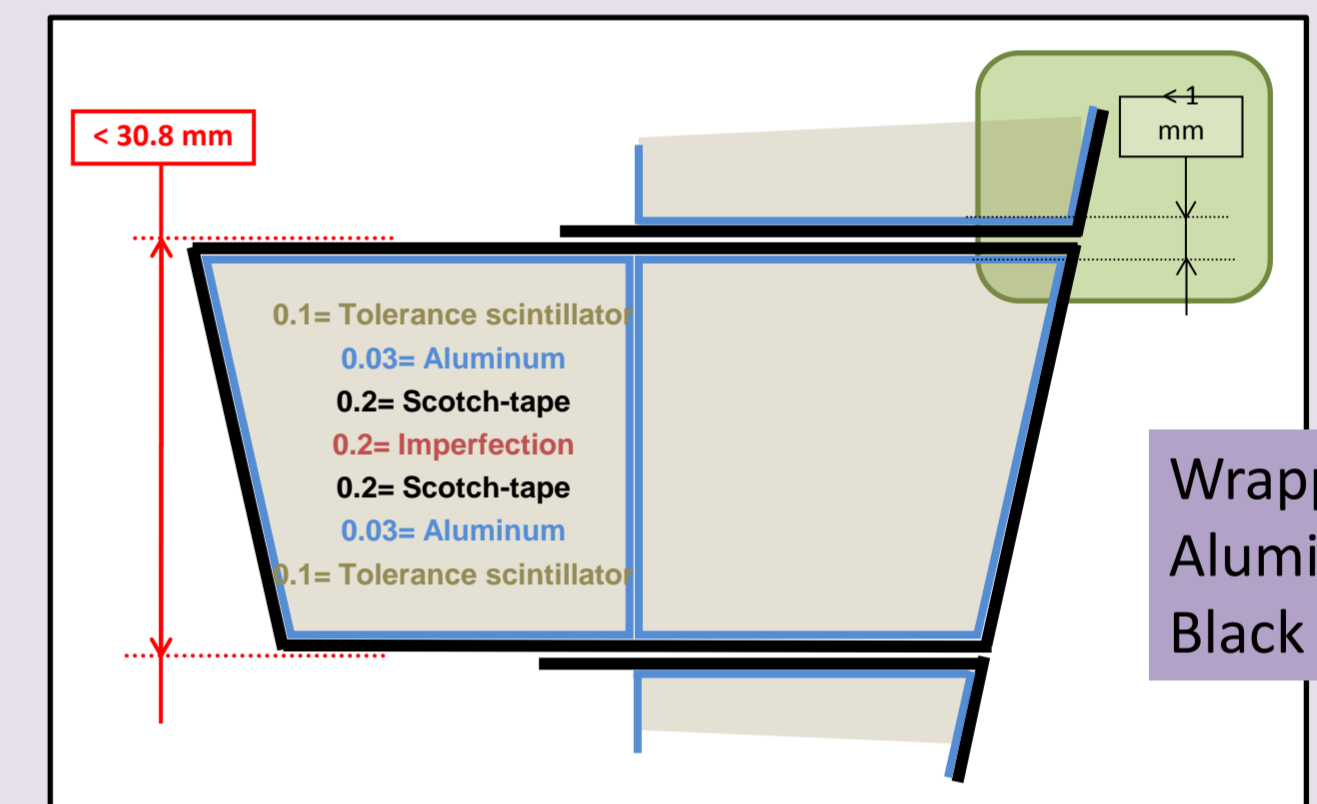
Dedicated assembling room

Three positioning tools for the gluing procedure

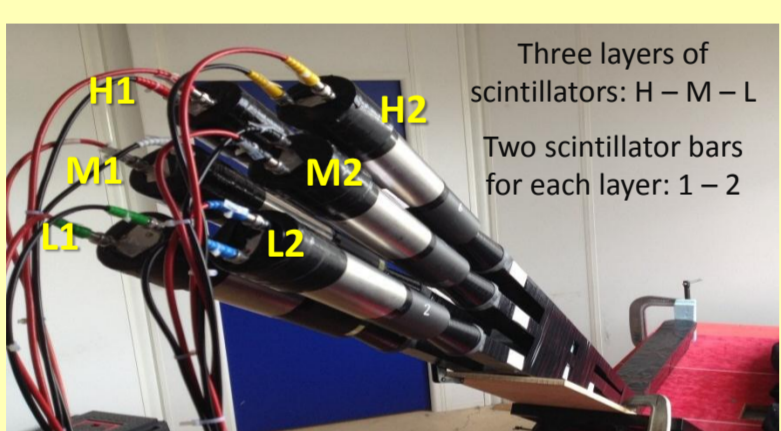


The wrapping procedure has to be very careful to respect the keep-in volumes and clearance requirements

	Min inside radius [mm]	Max outside radius [mm]	Radial thickness [mm]
Keep-out zone	282	290	8
CND	290	383	93
Keep-out zone	383	390	7

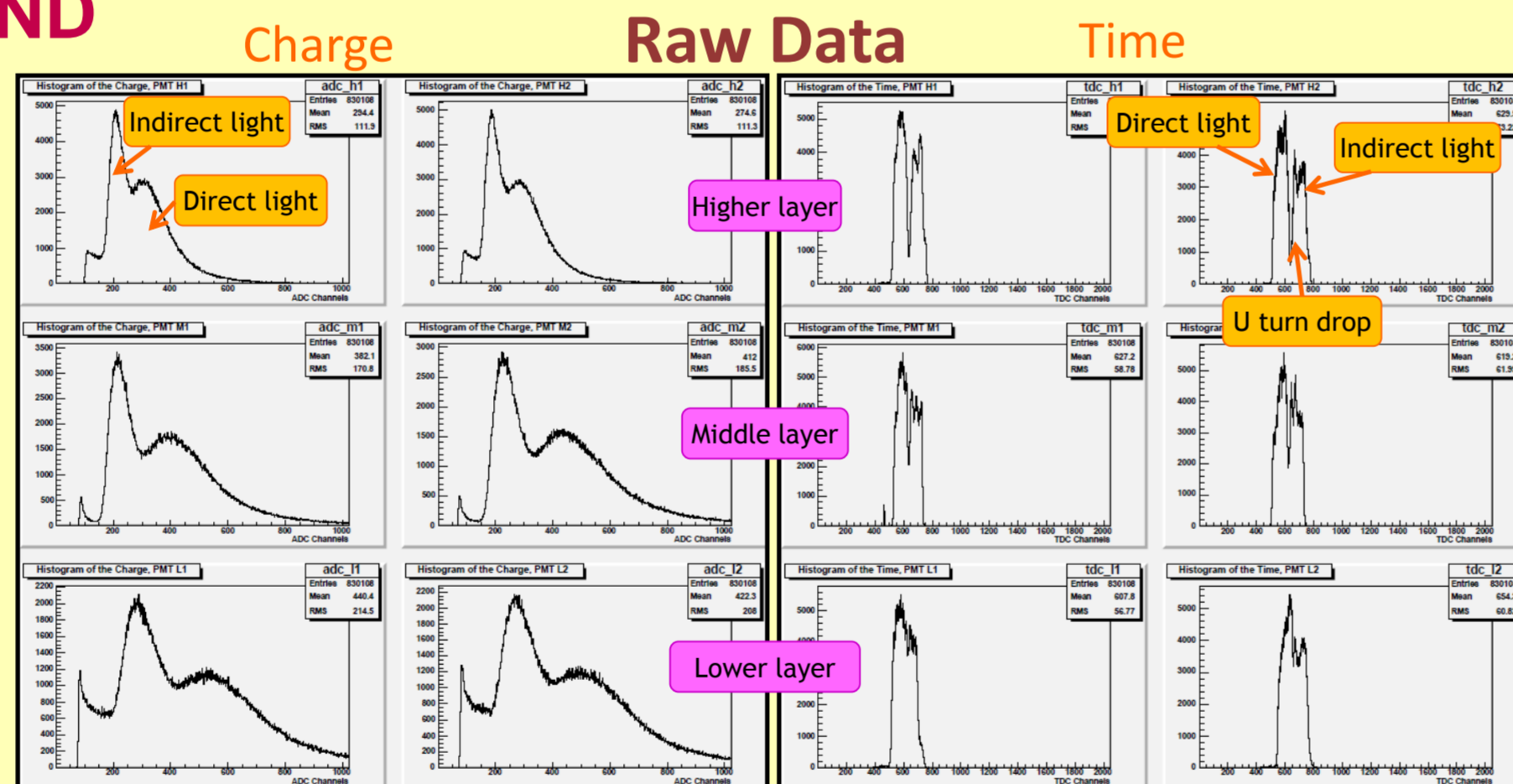


## Test and characterization of the CND

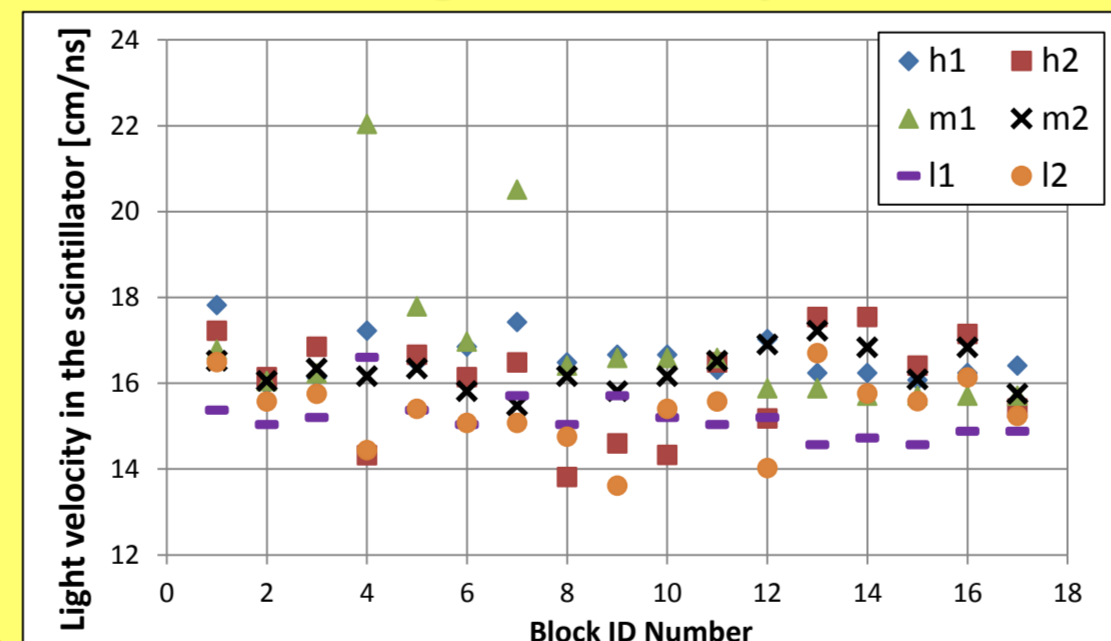


One week needed to characterize each block with cosmic rays (2.0M events accumulated)

- Light collection
- Light velocity in the scintillator
- Light attenuation in the scintillator
- Time resolution

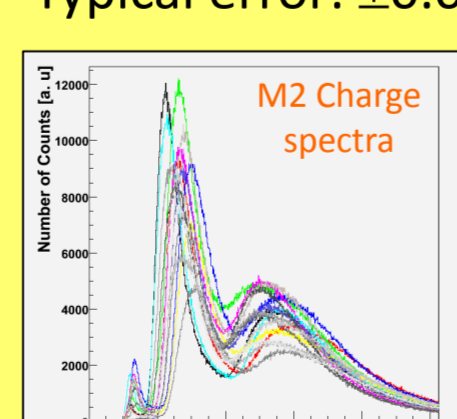
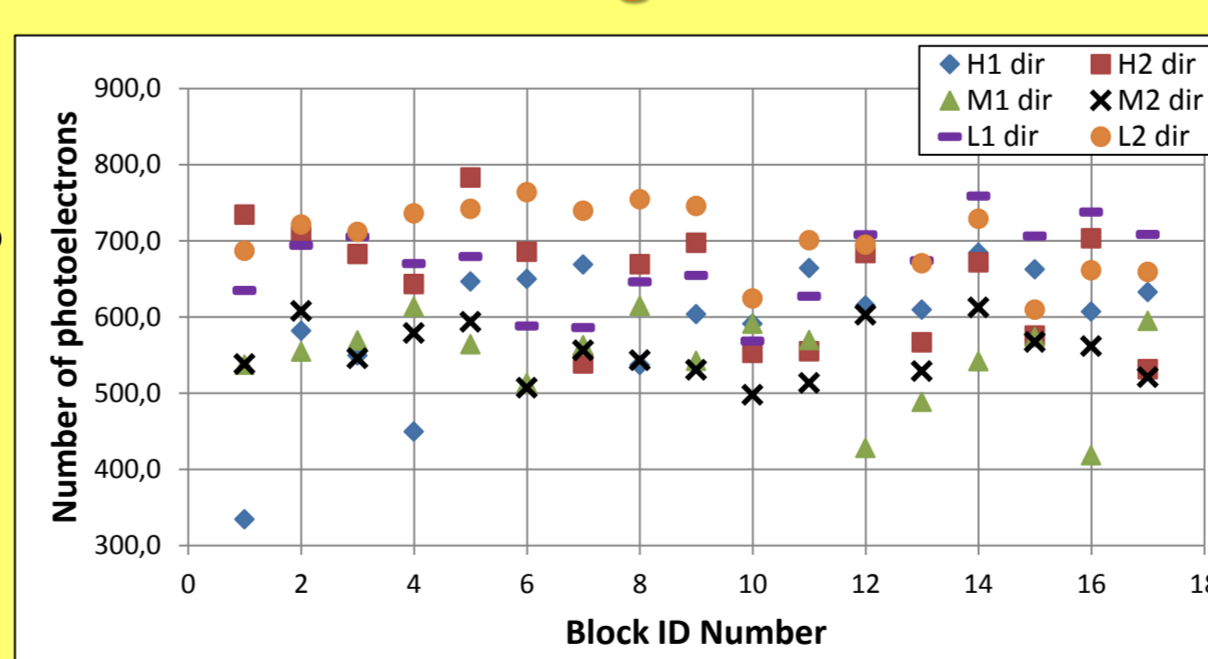


### Light velocity



- Assumed  $\sigma_{\text{TOF}} = 150$  ps
- Length<sub>h</sub> = 73.43 cm
- Length<sub>m</sub> = 70.0 cm
- Length<sub>l</sub> = 66.57 cm
- Typical error:  $\pm 3.5\%$

### Light collection



Variation (between  $\pm 7\%$  and  $\pm 15\%$ ) in the light collection is due to variation in the gluing, wrapping and optical coupling with the PMT

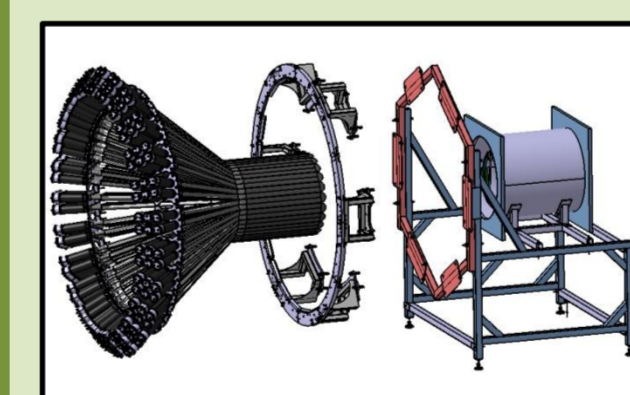
## The mechanical structure



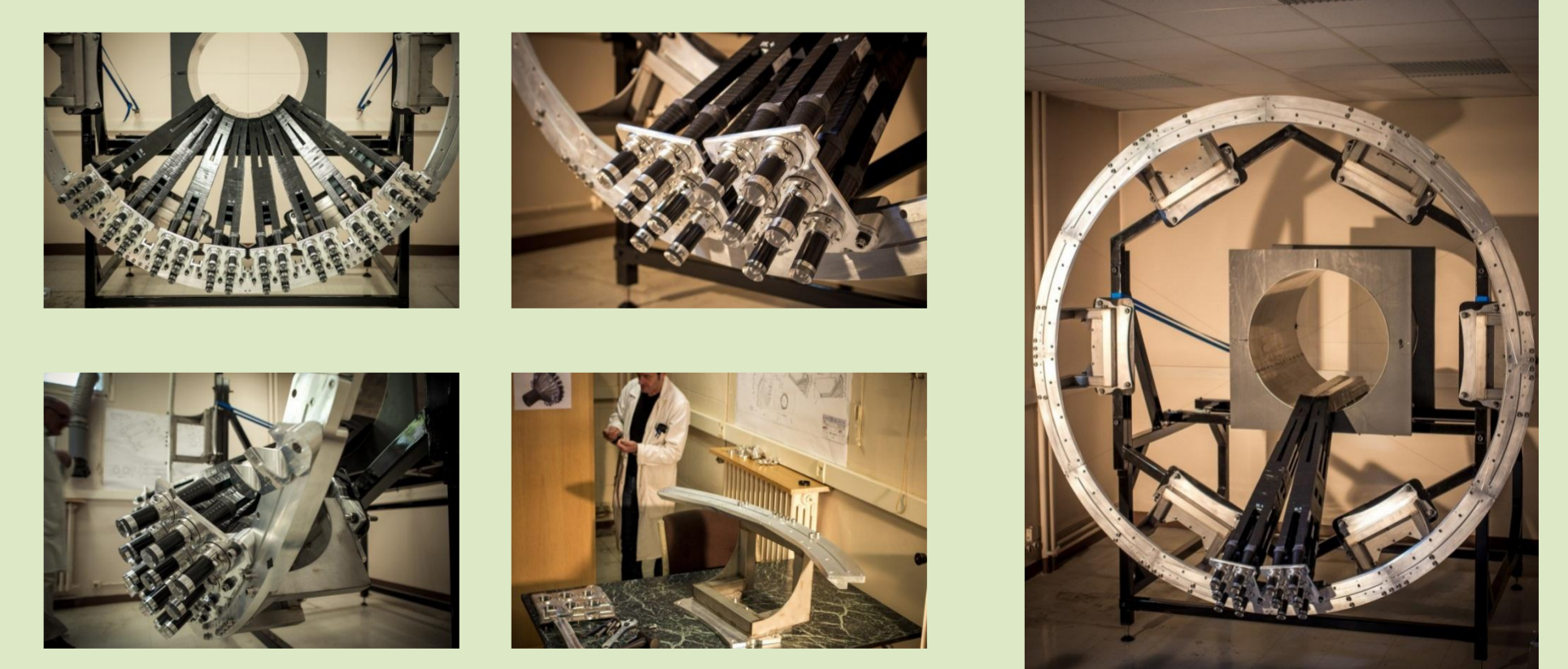
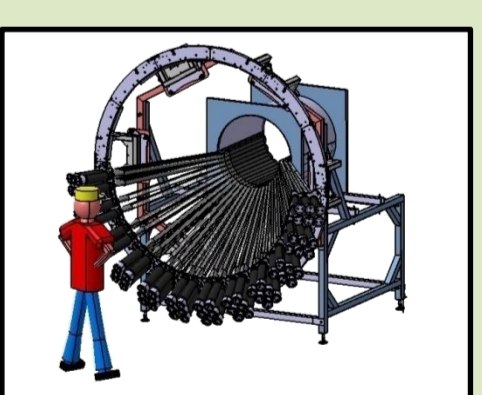
The support structure designed to integrate the CND in the CLAS12 apparatus is made up of 6 separate Aluminum arches that are fastened together to form a ring, which is in turn attached to the magnet by means of stainless-steel brackets

On the stainless-steel bracket:  
Max stress = 50 Mpa  
Deflection = 0.1 mm  
PMT + plate + arch = 120 kg

On the arch:  
Max stress = 16 Mpa  
Deflection = 0.17 mm  
4x(PMT + plate + arch) = 120 kg



At IPNO we built a mechanical prototype to reproduce the magnet geometry in order to test the mounting of the structure and the positioning of the blocks



Once each block has been fully characterized with cosmic rays it is positioned in the structure to test the stability and the strength of the final CND assembly. So far we installed 16 blocks in the structure

## Conclusion and future work

The CND construction started in December 2013 at the Institut de Physique Nucléaire d'Orsay. We assembled 21 blocks and tested, with cosmic rays, 17 of them out of the 24 of the final design. For all the tested blocks we measured a time resolution  $\sigma_{\text{TOF}}$  better than 160 ps thus satisfying the requirements, in terms of time properties, needed to perform the desired hadron physics experiment.

At the present time we are organizing the shipping that is planned for spring 2015. The installation will take place one year later and the experiment will start on 2017