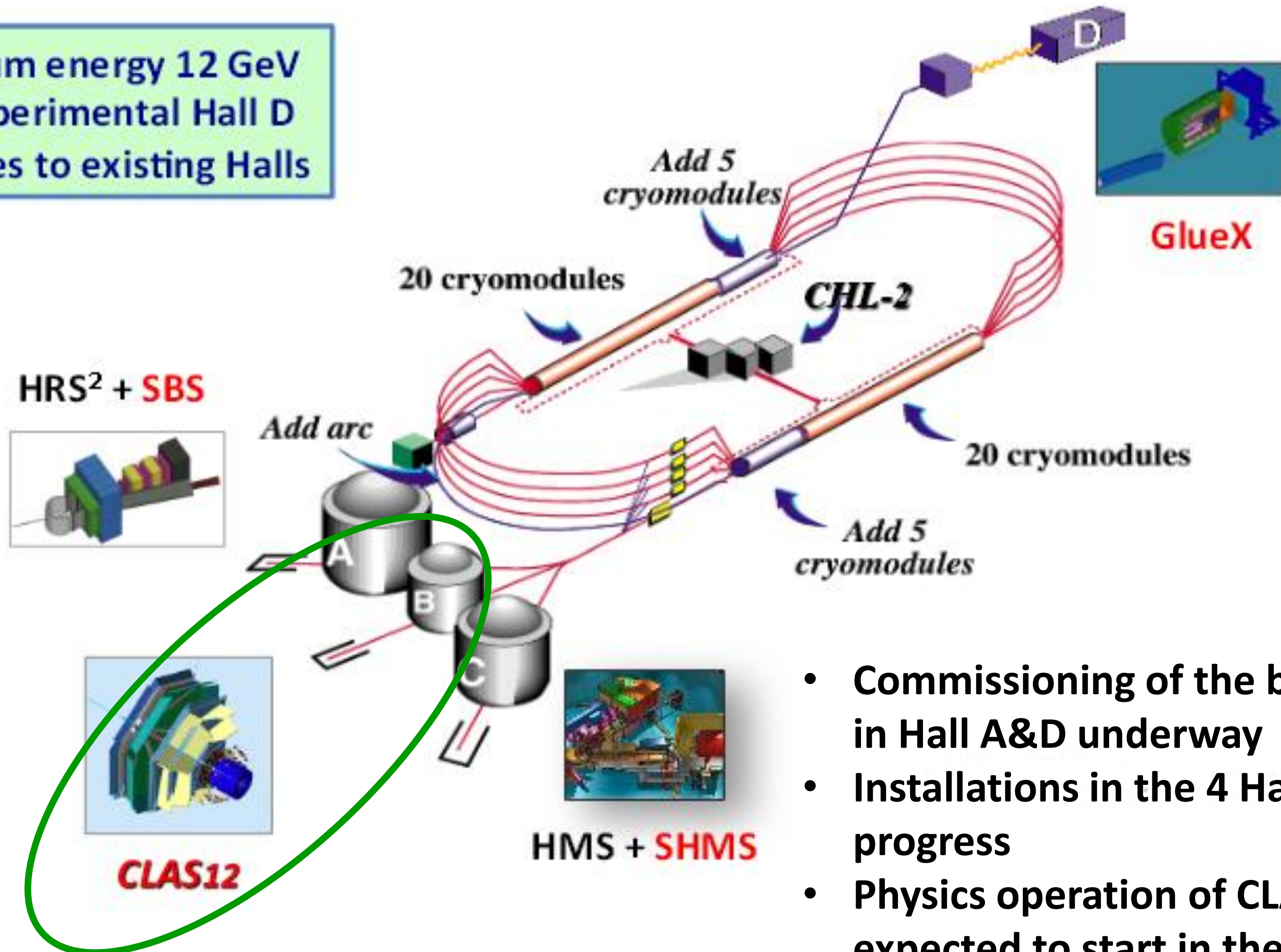
JLab12 status and activities

Marco Mirazita

49th Meeting of the LNF Scientific Committee – May 18, 2015 - Frascati

JLab from 6 to 12 GeV

Maximum energy 12 GeV
New Experimental Hall D
Upgrades to existing Halls



CLAS12@Hall B

- Commissioning of the beam in Hall A&D underway
- Installations in the 4 Halls in progress
- Physics operation of CLAS12 expected to start in the second half of 2017

Nucleon structure functions

How can we build a multidimensional picture of the nucleon ?

Non-perturbative QCD is complicated

- **Lattice QCD**
- **Phenomenological description → structure functions**

Wigner Functions: $W\left(x, \vec{b}_\perp, \vec{k}_\perp\right)$

Transverse Momentum Distributions

- **3D imaging in momentum space**
- **semi-inclusive processes**

Generalized Parton Distributions

- **longitudinal momentum and transverse spatial imaging**
- **exclusive processes**

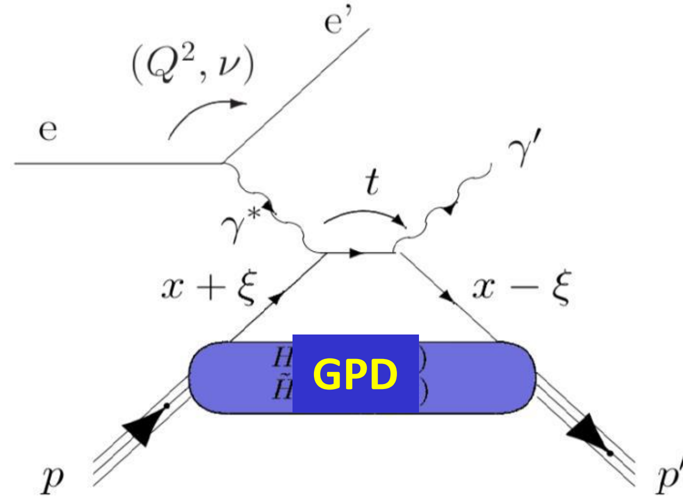
integrations, FT, forward limits, etc.

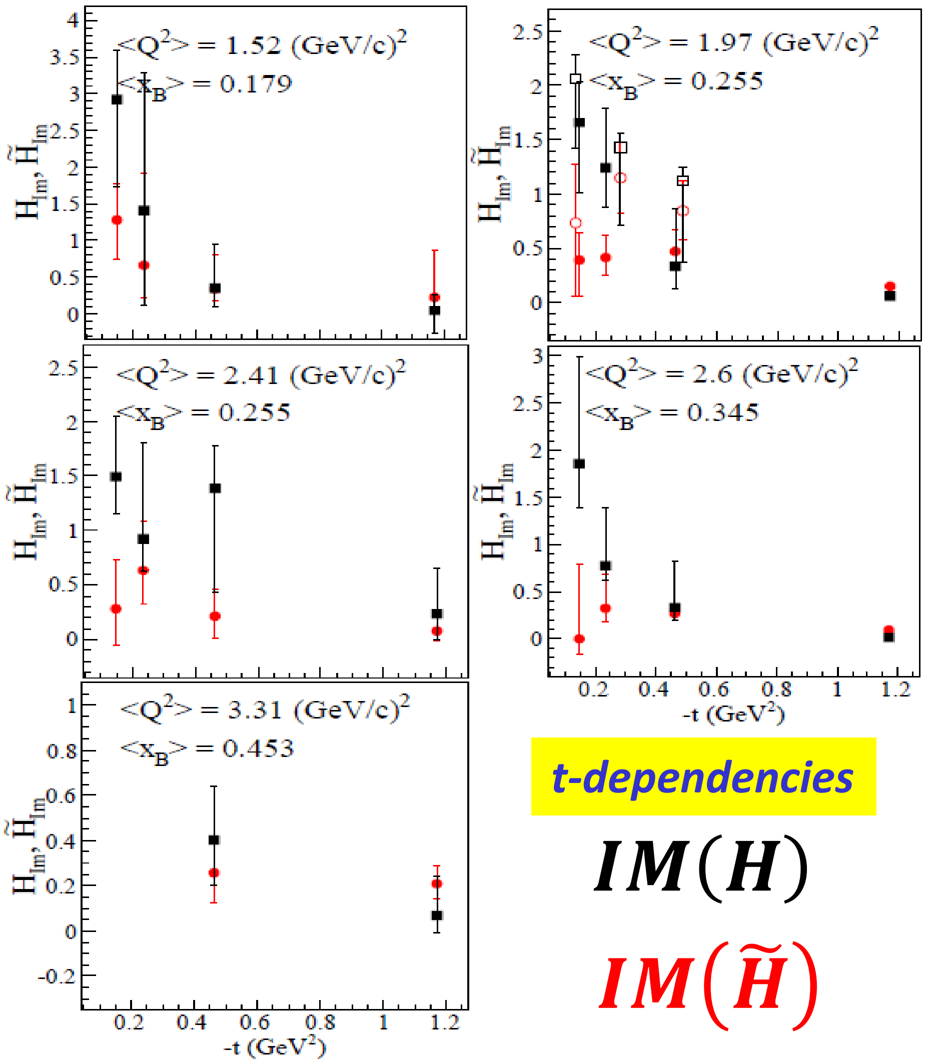
- **Elastic Form Factors, Parton Distributions Functions**
- **Nucleon charges**
- **Parton Angular momentum**

GPD measurements

Deeply Virtual Compton Scattering

$$\vec{e}\vec{p} \rightarrow e' p' \gamma$$





t-dependencies

$IM(H)$

$IM(\tilde{H})$

$IM(H)$ → unpol. → electric charge

- growing as t → 0
- FT → spread in the nucleon volume

$IM(\tilde{H})$ → helicity → axial charge

- almost flat
- FT → center of the nucleon

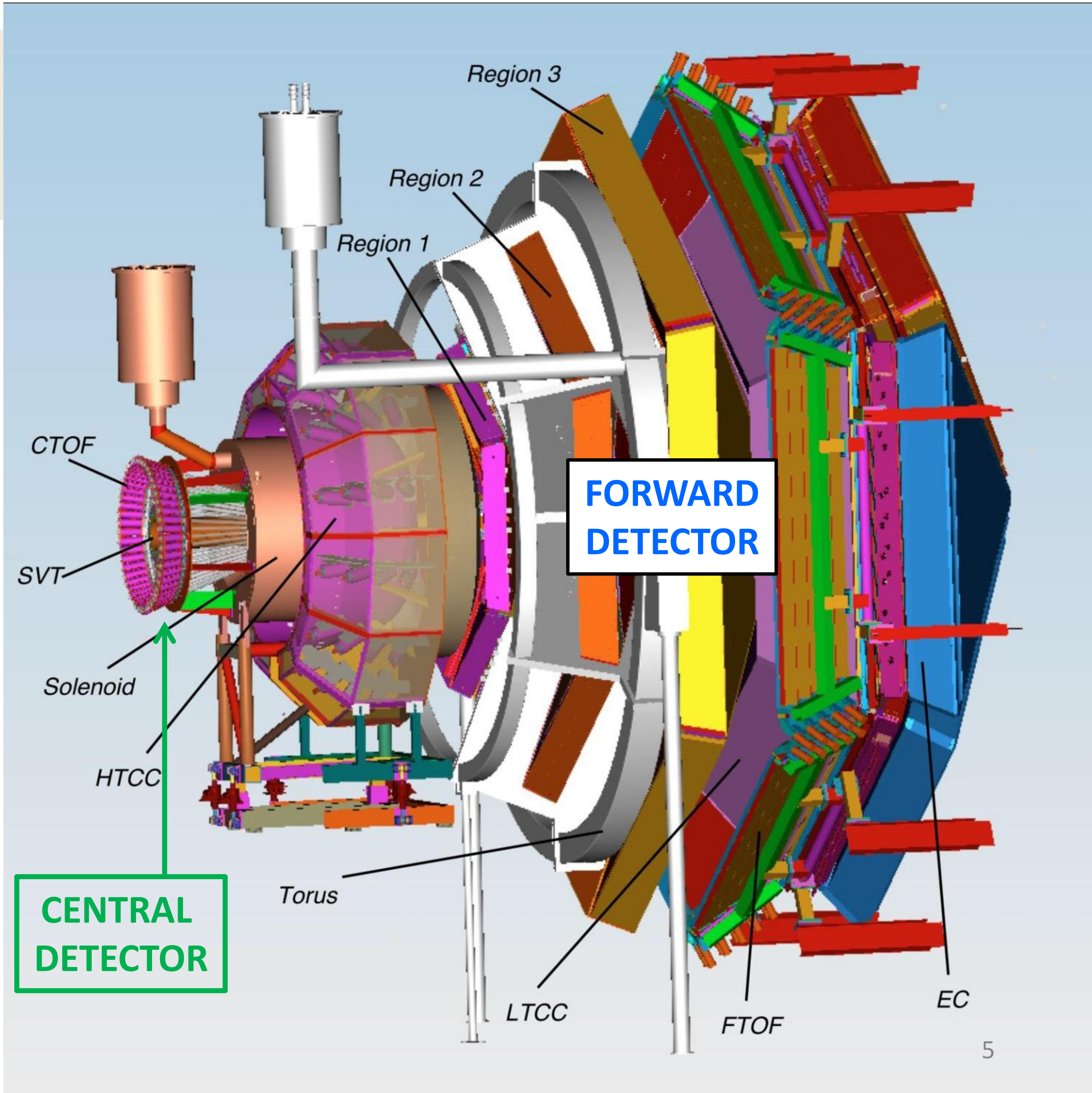
CLAS Coll., S. Pisano et al.
PR D91 (2015) 5, 052014
PRL 114 (2015) 3, 032001

The CLAS12 spectrometer

- Luminosity up to 10^{35} cm^{-2} s^{-1}
- High polarization electron beam
- H and D polarized targets
- Wide acceptance

CENTRAL DETECTOR
- solenoidal field
- vertex tracker
- time-of-flight

FORWARD DETECTOR
- toroidal field
- 6 sector geometry
- vertex tracker
- three regions of drift chambers
- time-of-flight
- two threshold Cherenkov counters
- preshower
- EM calorimeter



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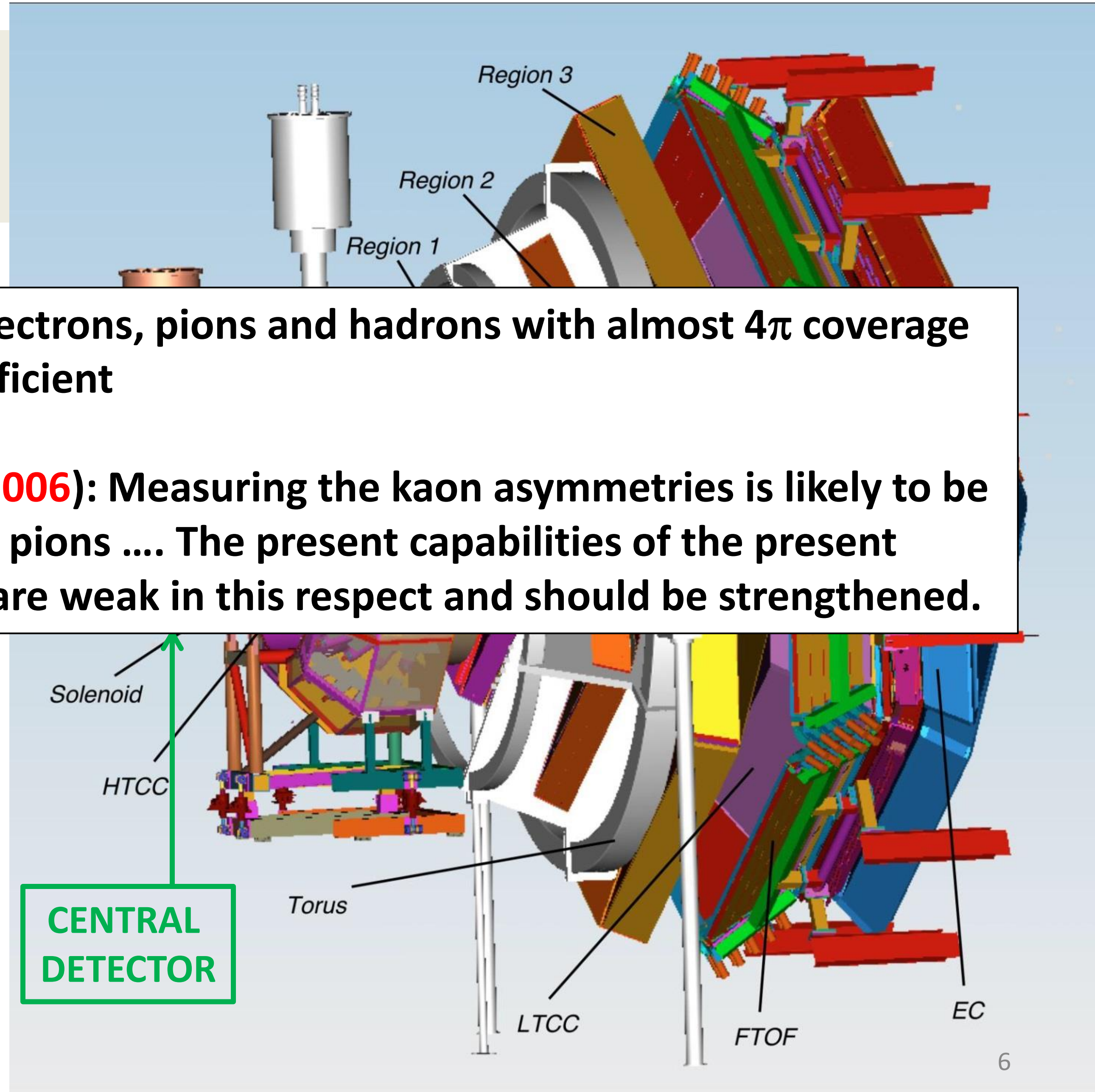
Good PID for electrons, pions and hadrons with almost 4π coverage
Kaon ID not sufficient

PAC30 report (2006): Measuring the kaon asymmetries is likely to be as important as pions …. The present capabilities of the present CLAS12 design are weak in this respect and should be strengthened.

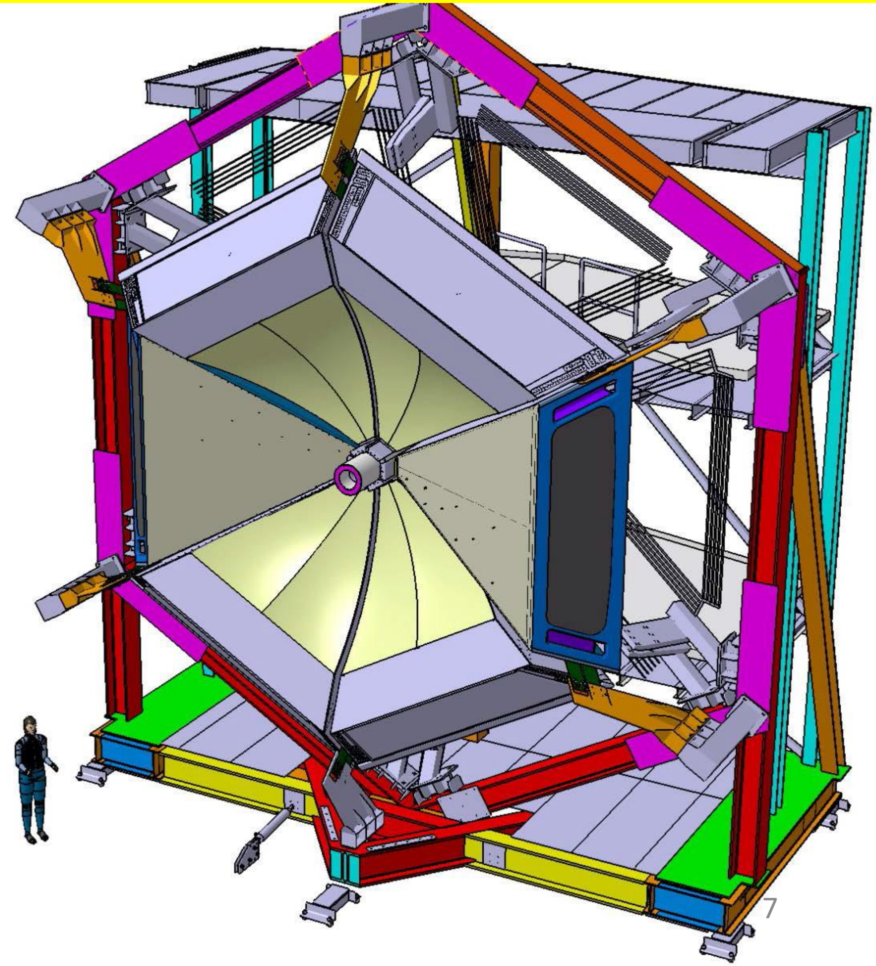


The CLAS12 RICH project

- Initially proposed by INFN LNF and Fe (2010)
- Construction of the first sector approved by JLab & DOE (Sep. 2013)
- Special funding by MIUR for the second sector (Sep. 2013)

The RICH Collaboration
INFN Ba, Fe, Ge, LNF, ISS/Roma1
JLab, Argonne, Duquesne U., Connecticut U. (USA), Glasgow U. (UK), Mainz (Germany), Kyungpook U. (Korea), UTFSM (Chile)

The goal:
4σ π/K/p separation for 3-8 GeV/c momenta



First RICH sector:

- to be ready for the beginning of CLAS12 operation with unpolarized and longitudinally polarized targets

Second RICH sector:

- necessary to extend the kinematic coverage at higher p_T and to operate with transversely polarized targets

The RICH detector

Components

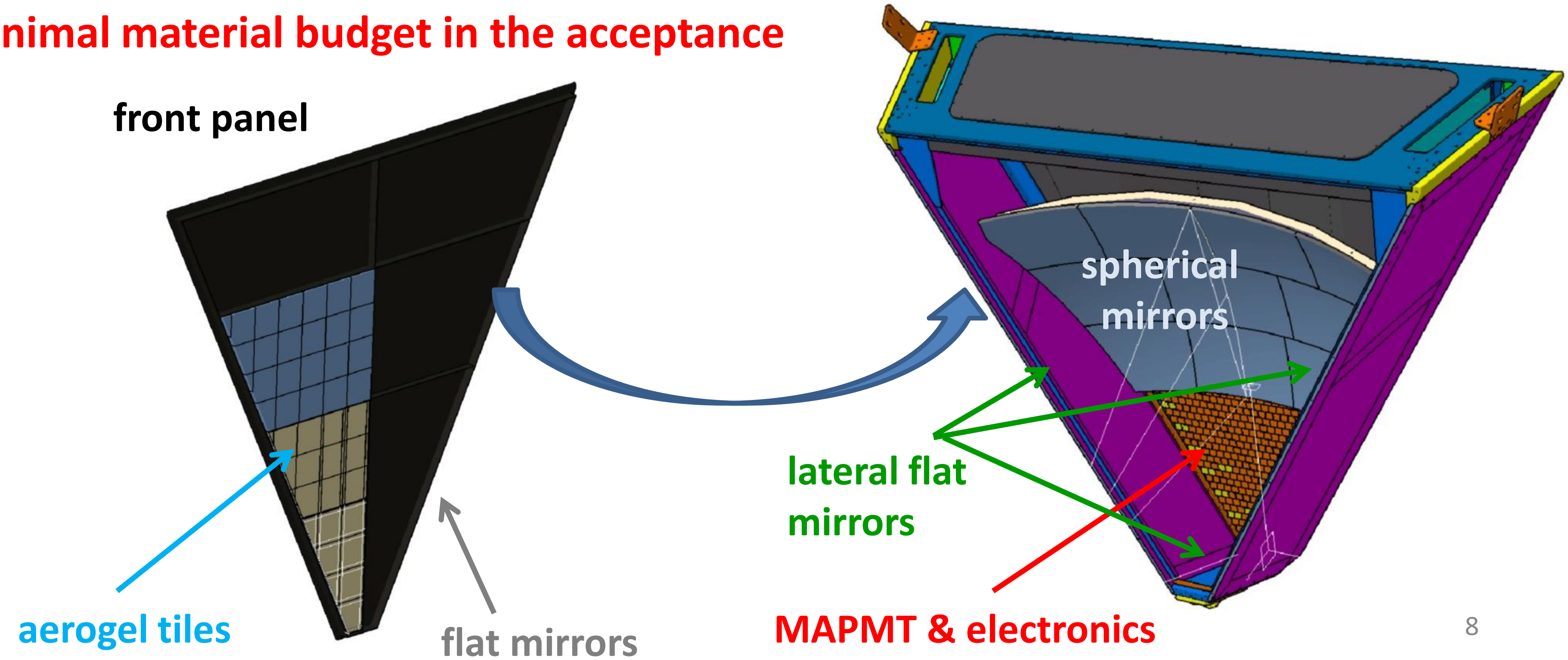
- aerogel radiator: imposed by momentum range
- MultiAnode PMT: to match the aerogel photon spectrum
- mirrors: to reduce the photodetector area

Main constraints:

- geometry fixed by CLAS12
- minimal material budget in the acceptance

LNF activities

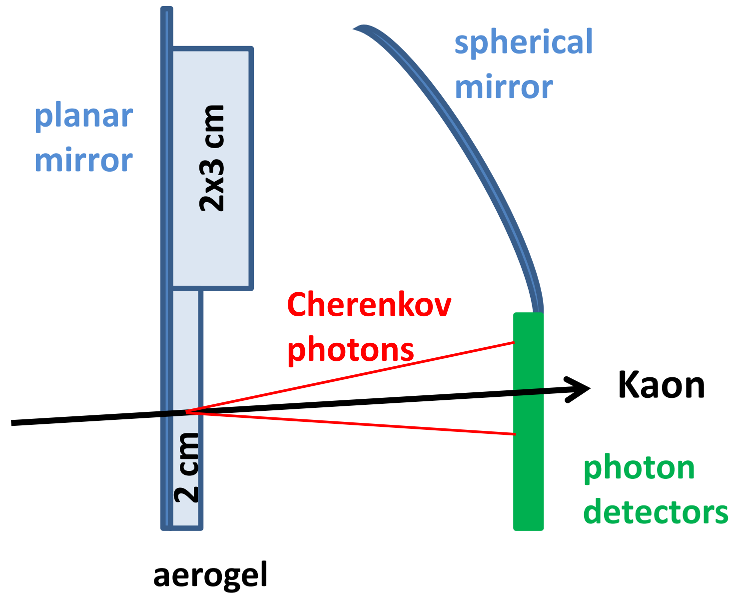
- R&D and prototyping
- selection of the photon detectors
- design of the module
- test of the mirrors



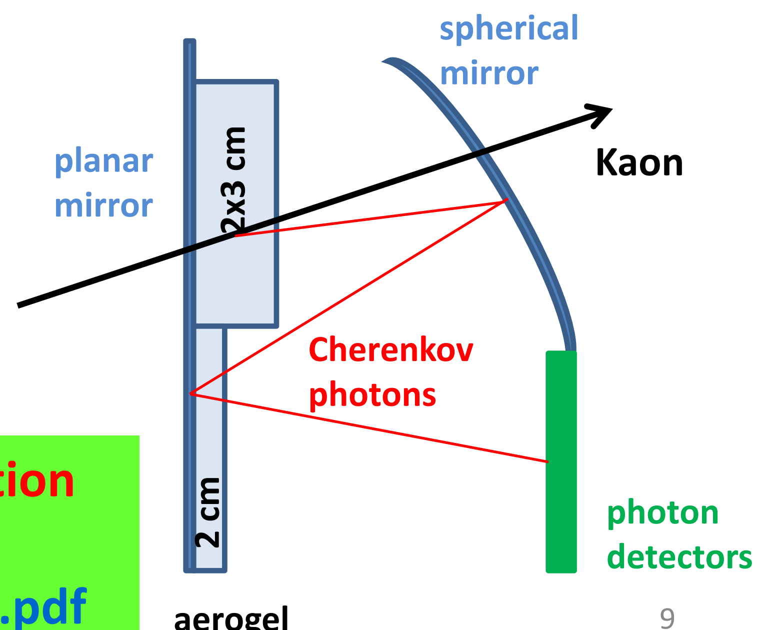
The RICH concept

Hybrid solution:
proximity gap plus mirror focusing

- **Small polar angle particles**
  - **1m gap**
  - **direct imaging of the Cherenkov photons**
  - **thin radiator**



- **Large polar angle particles**
  - **about 3m path length after mirror reflections**
  - **double passage of Cherenkov photons in aerogel**
  - **thicker radiator to compensate photon loss**



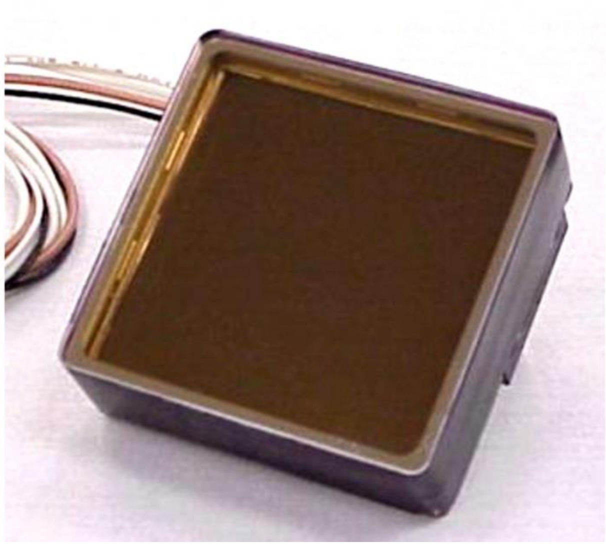
Simulations show that the required π/k/p separation can be achieved in the whole momentum range
http://www.lnf.infn.it/~mirazita/RICH/RICH_TDR.pdf

Photodetectors

Multi-Anode Photomultiplier tubes Hamamatsu H8500 & H12700
- 8x8 matrix of 5.8x58 mm^2 pixels
- packing fraction ~90%
- gain ~10^6
- mature technology

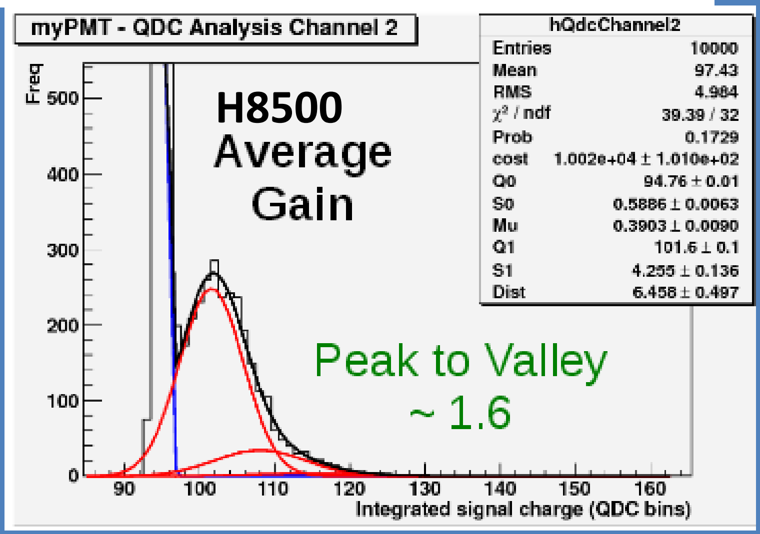
H8500 extensively studied at LNF
- validation of the SPE capabilities
- ageing tests (n and γ)

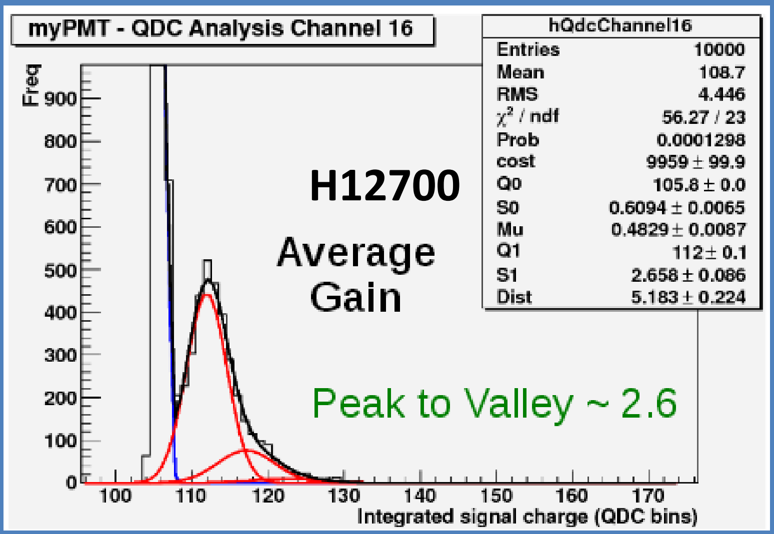
New H12700 released
- better SPE detection



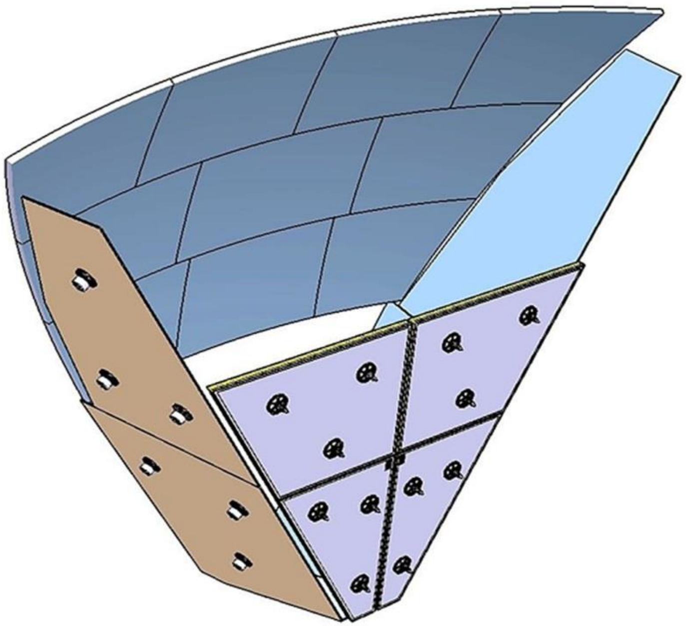
R. Montgomery et al., arXiv:1409.3622, NIM in print

MAPMT response to a laser beam at few photon intensity





The mirror system



Ten spherical mirrors in Carbon Fiber sandwich with a honeycomb core

- minimal material budget
- radius of curvature 2.7 m

Four planar mirror made by a sandwich of thin glass layers with a honeycomb core

- small material budget
- lower cost than carbon fiber

Four planar mirrors on the lateral sides and one on the floor

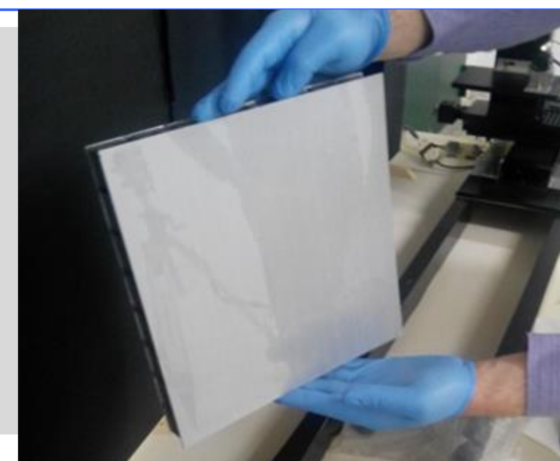
- out of acceptance, no material budget issues

The CFRP spherical mirror is the more critical one in terms of performances

A careful R&D phase has been carried on to identify the producer

CFRP mirror demos produced by different companies

→CMA (Tucson USA): produced mirrors for HERMES, LHCb



Spherical mirror tests - 1

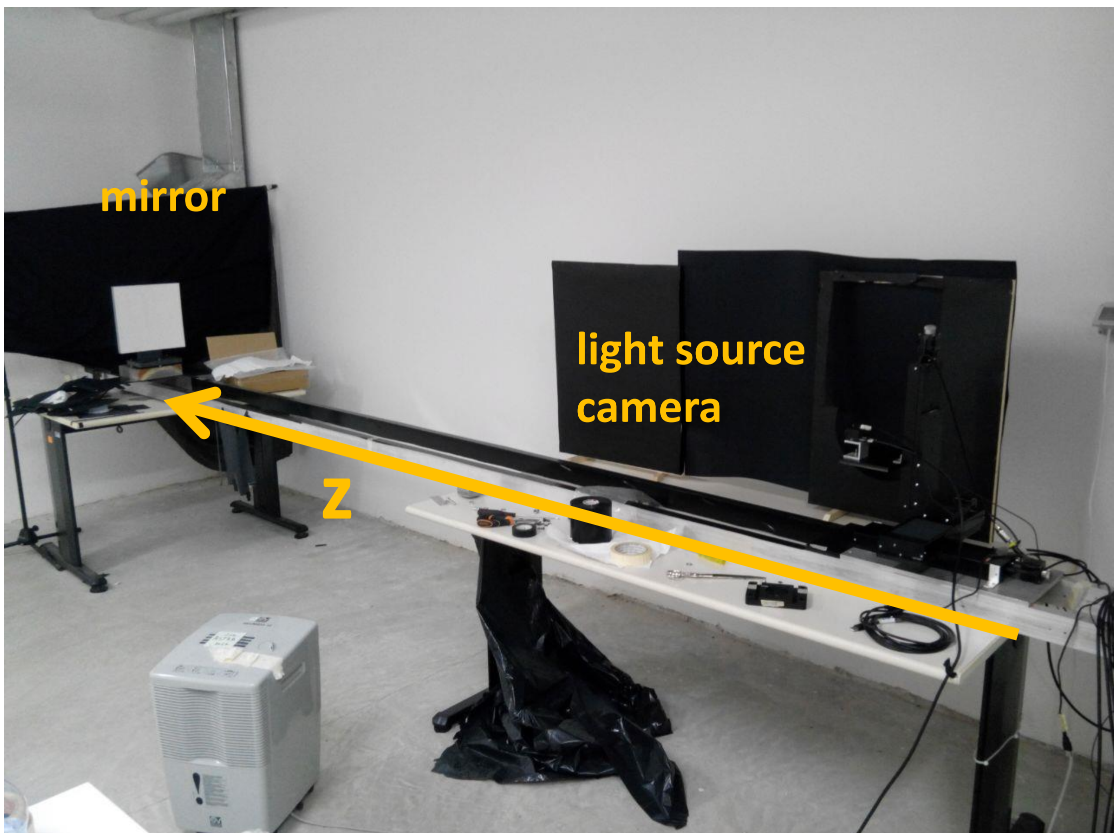
The surface quality of the mirrors must be tested at various scales

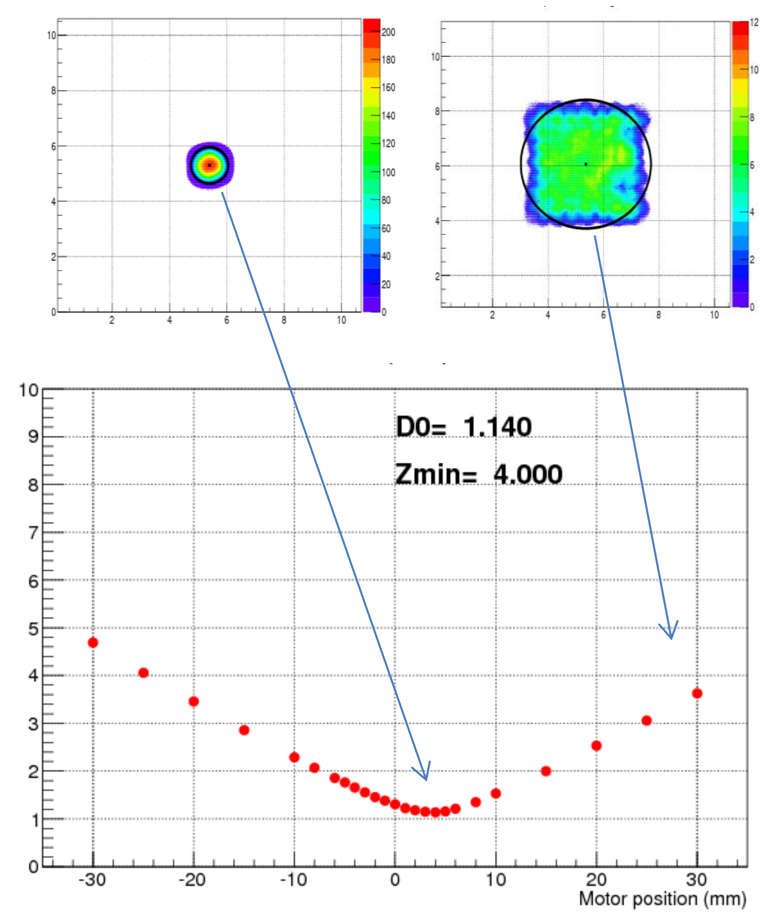
- **surface accuracy, μm: related to the resolution on the reflection angle**

A spot size measurement provide information on the average surface accuracy

- **the image of a pointlike source at the CoC is a point**
- **σ_θ ~mrad → D_0 ~ mm**

$$\sigma_\vartheta = \frac{D_0}{8R}$$



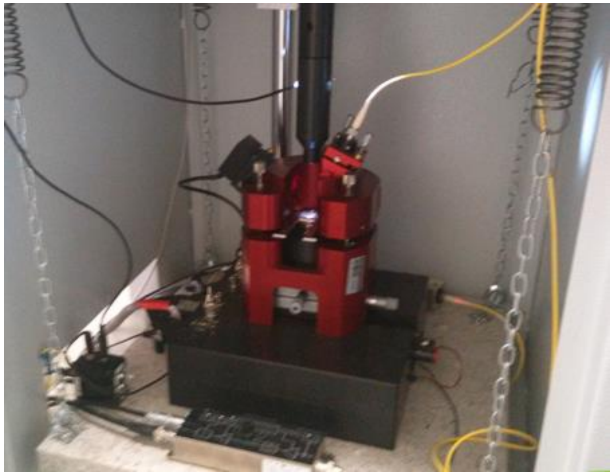


Spherical mirror tests - 2

The surface quality of the mirrors must be tested at various scales

- **surface roughness, nm: related to the reflectivity of the mirror**

$$R \propto \exp\left[-\left(\frac{4\pi\sigma_r \cos\vartheta_i}{\lambda}\right)^2\right]$$



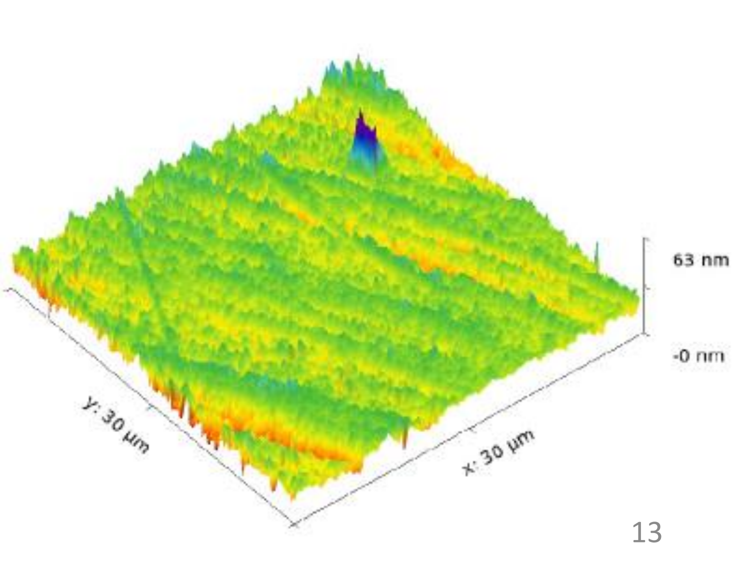
To have R~1 at λ=400 nm (aerogel)
σ_r ~ few nm

Roughness of several sample of CFRP measured at LNF with an Atomic Force Microscopy

Thanks to F. Micciulla

RMS of the height profile
$\sigma_r = 2.5 \div 5.0$ nm

G. Angelini, Thesis Univ. of Rome1 (2014)



Mechanical structure

The construction of the mechanical structure of the RICH is responsibility of LNF

D. Orecchini, A, Orlandi, S. Tomassini, A. Viticchie'

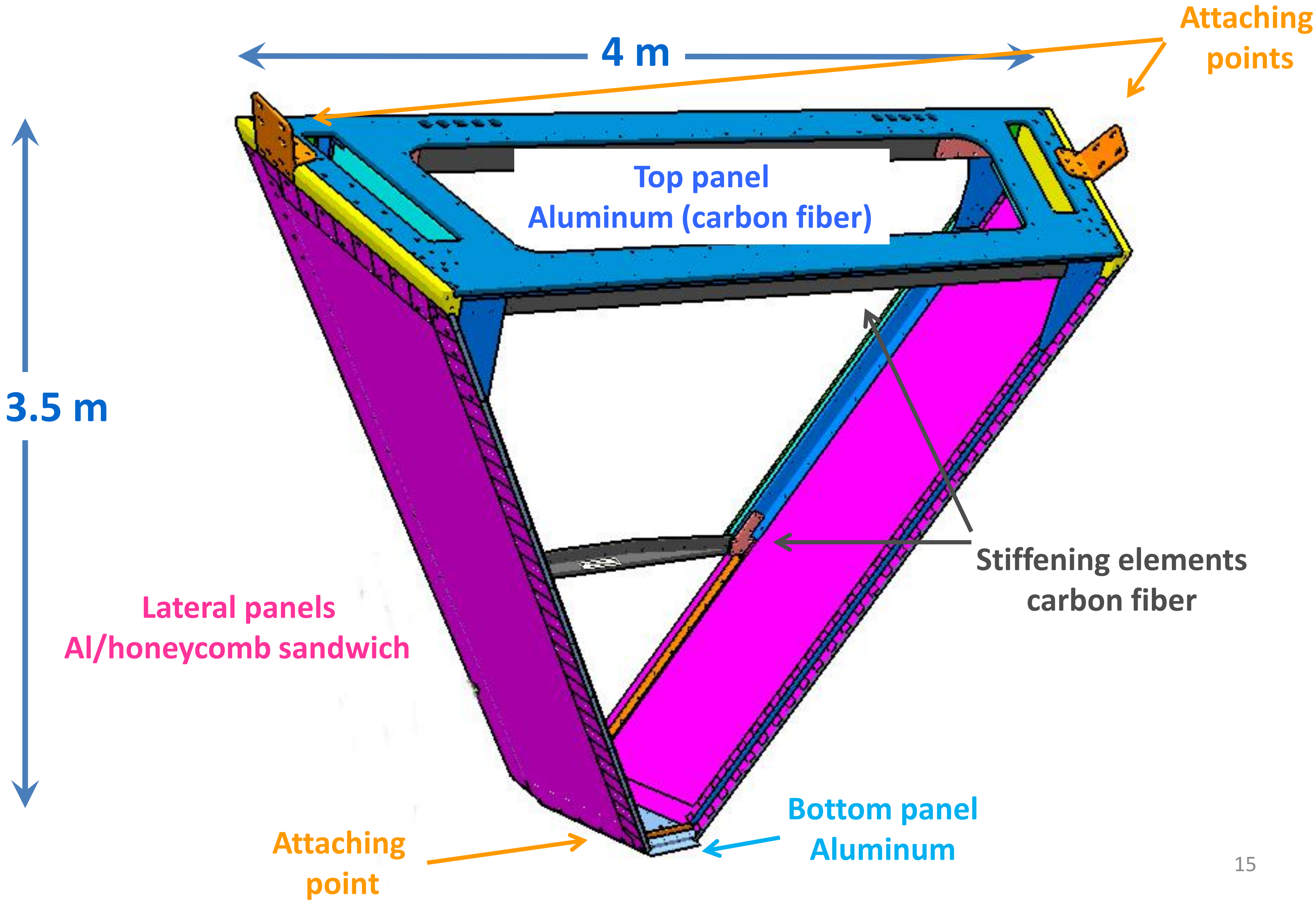
It includes:

- **external envelope in Al alloy and Al honeycomb panels with carbon fiber stiffening elements**
- **supporting panel for the Front-End electronics**
- **housing for the aerogel tiles**
- **mounting systems for the spherical and flat mirrors**

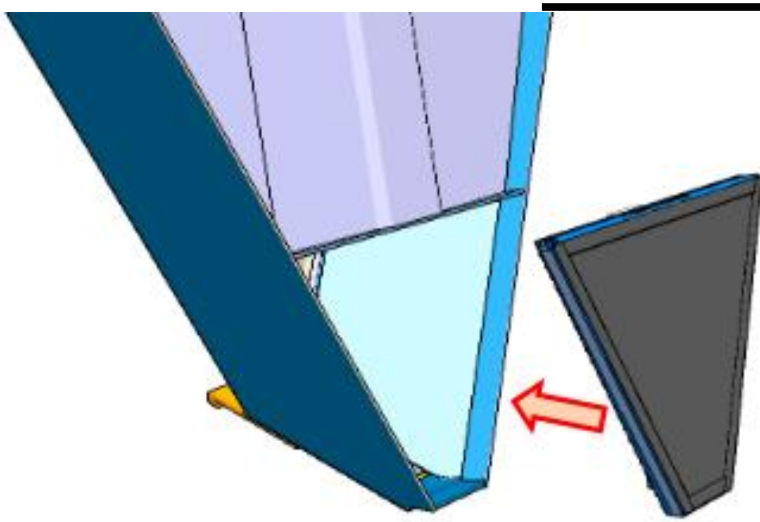
Tender for the construction on the RICH envelope awarded to "Tecnologie Avanzate SRL" (Veroli, Italy)

- company specialized in aeronautic constructions (Boeing, Augusta)

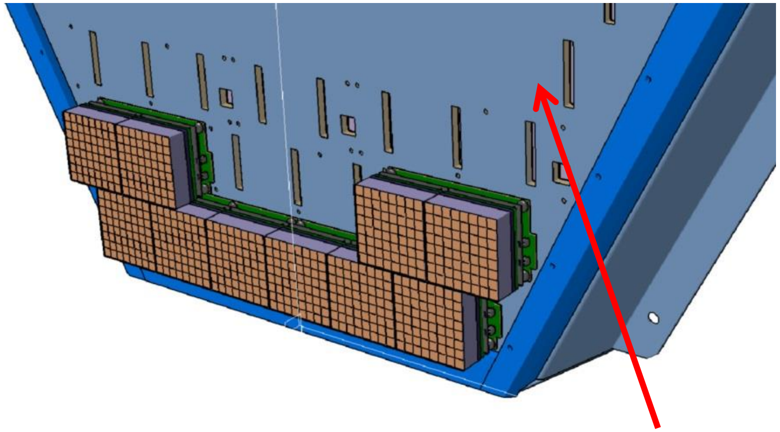
The RICH module



Electronic panel

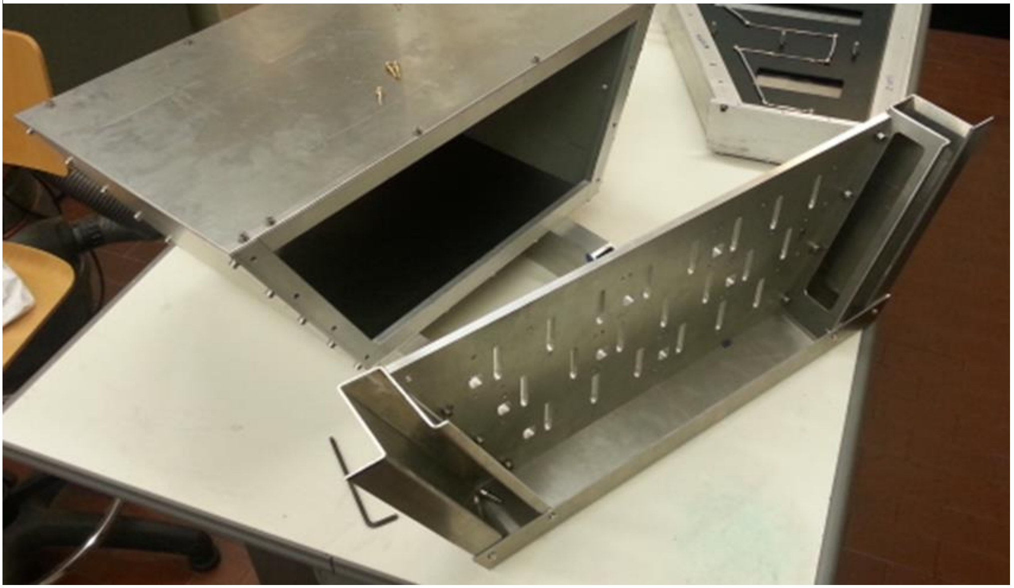


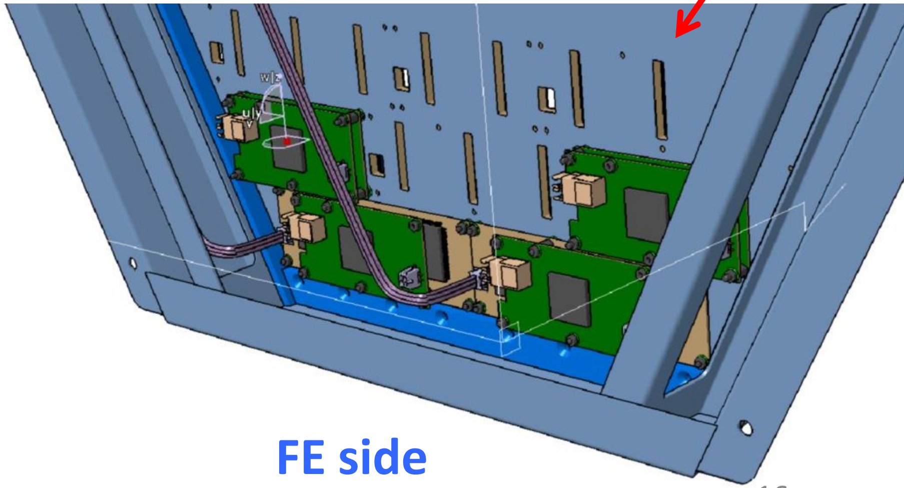
MAPMT side



Small prototype of the box made by LNF workshop
Tests of the assembly procedure and of the light-tightness of the panel underway

Supporting panel
Al honeycomb sandwich



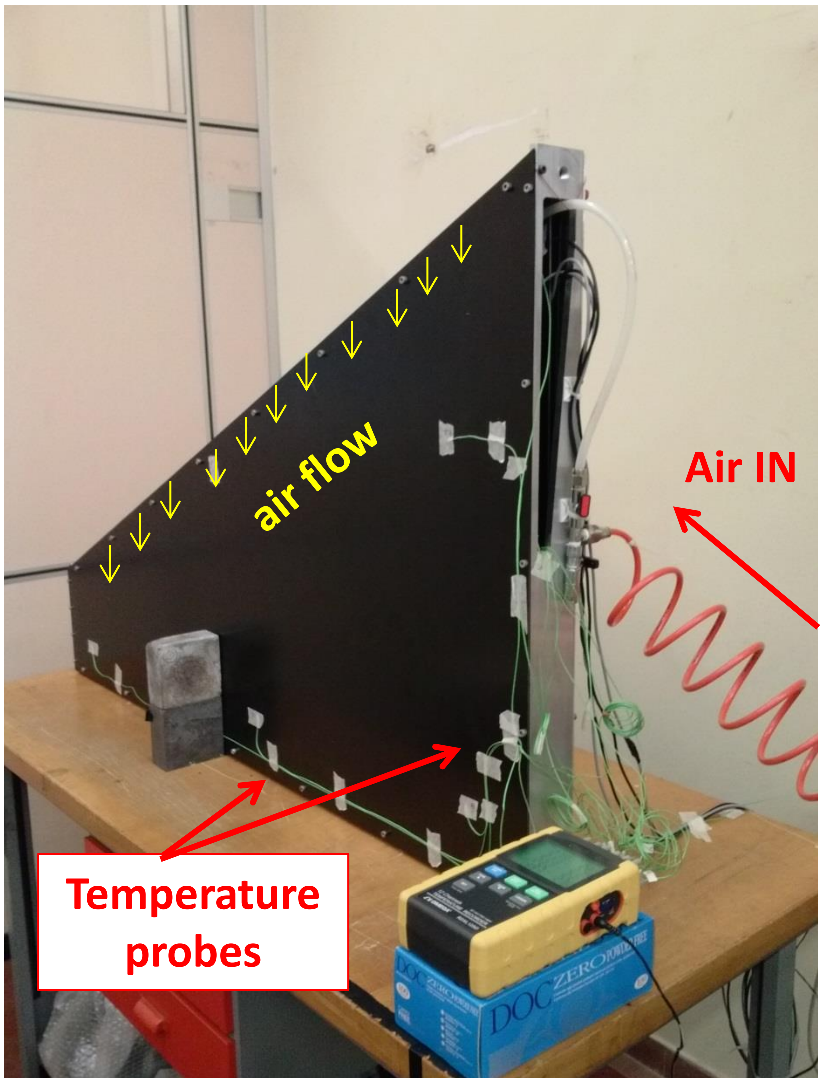


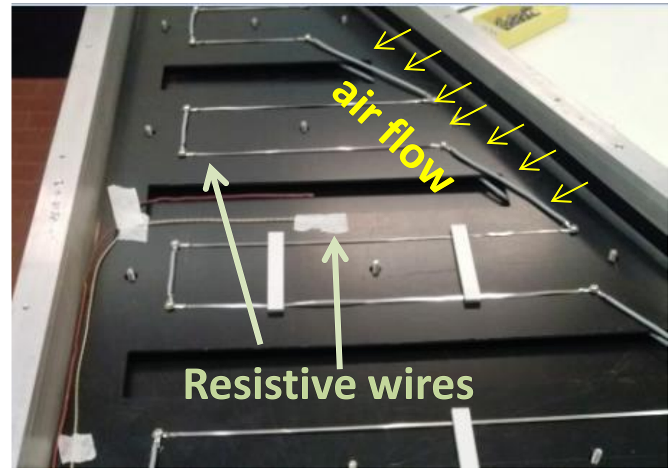
FE side

Cooling system

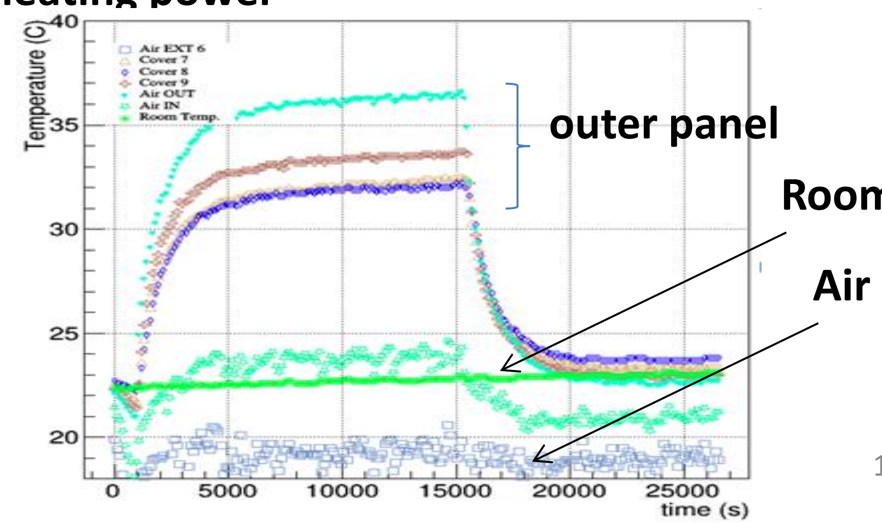
Expected heat production of the Front-End electronics is about 400W

- 100W from the MAROC3 ASICs
- 300W from the readout FPGA





Test of the cooling system underway with a real scale prototype of half panel
- resistive wires used to simulate the electronics heating power



RICH schedule

Mechanics

- **tender awarded, construction will start soon**
- **delivery to JLab in march 2016**

Aerogel

- **production of the first layer of the large angle sector underway**
- **order for the second layer by this year**

Mirrors

- **production of flat mirrors started**
- **production of spherical mirrors must begin by this year, expected completion in 14 months**

MAPMTs (JLab)

- **production underway, expected completion in may 2016**

Electronics

- **design of ASIC and FPGA boards completed, validation tests in progress**
- **production completion by beginning of next year**

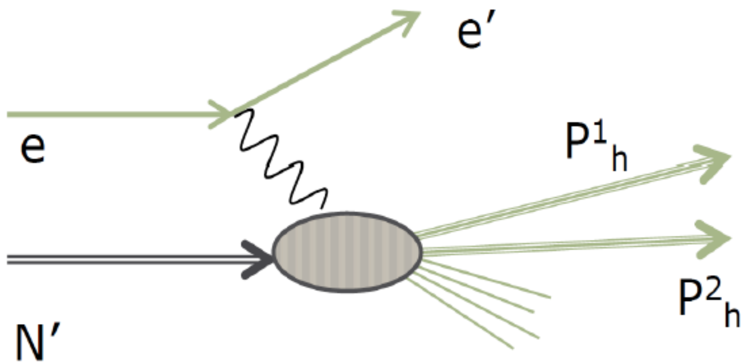
RICH installation

- **beginning of module assembly at JLab in 2016**
- **installation in the Hall B by June 2017**

additional slides

Dihadron SIDIS production

$$\vec{e}p \rightarrow e'\pi^+\pi^- X$$



Beam Spin Asymmetry

$$A_{LU} = \frac{\sigma^+ - \sigma^-}{\sigma^+ + \sigma^-}$$

Under well defined approximations

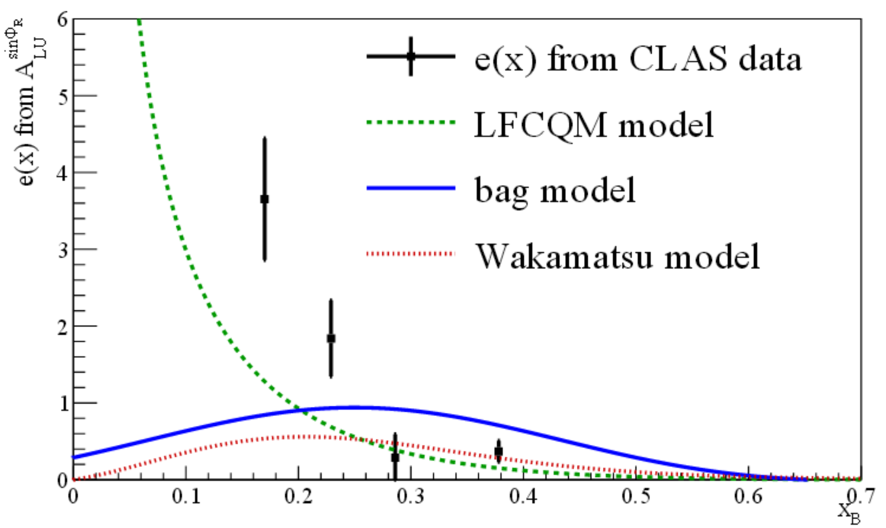
$$A_{LU} \propto \frac{e(x)H_1^{\angle}(z)}{f_1(x)D_1(z)}$$

known from Belle

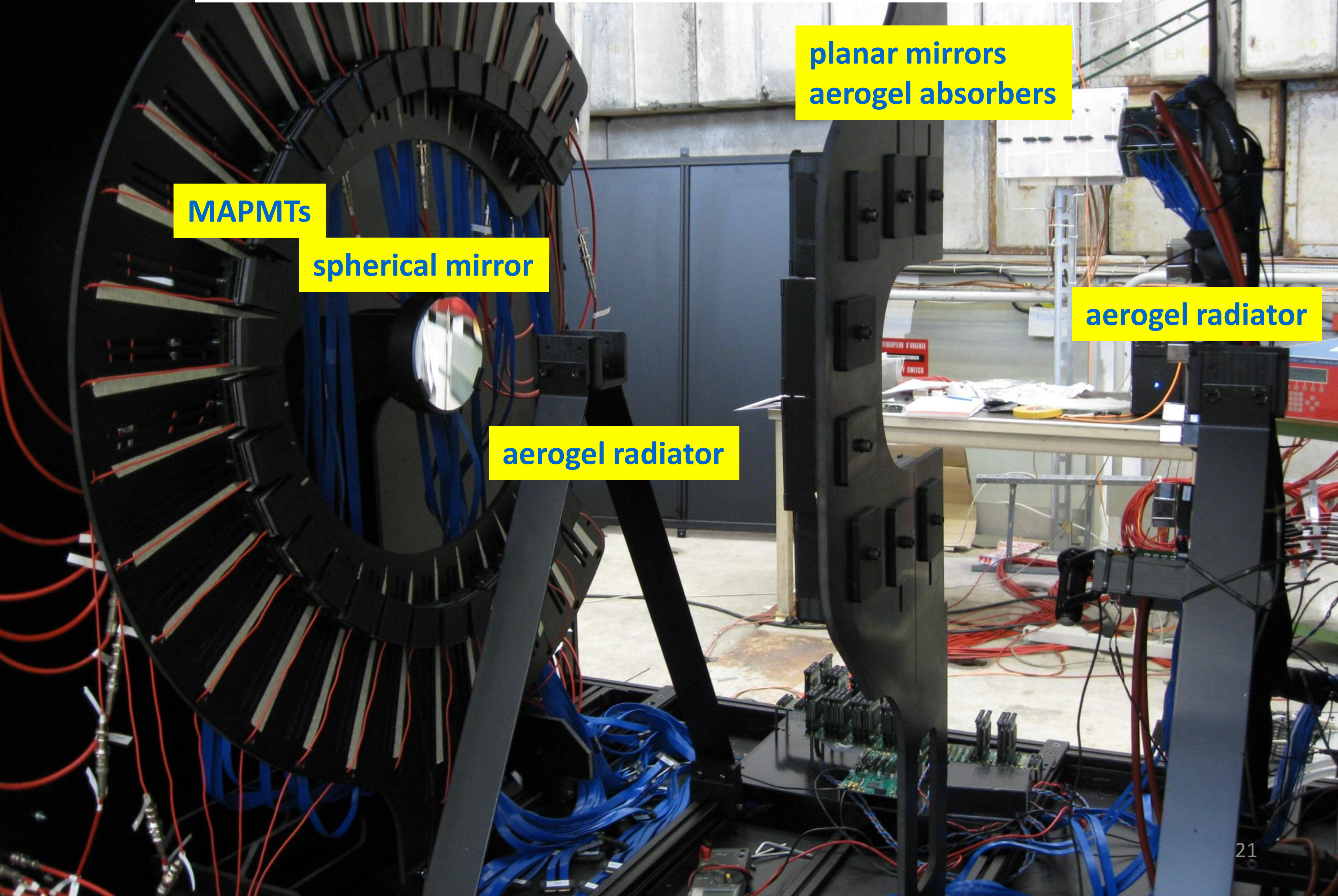
e(x) is related to the scalar charge and to the πN sigma-term

$$\int e_q(x,Q^2)dx = \sigma_q(Q^2)$$

$$\sigma_u + \sigma_d = \frac{\sigma_{\pi N}}{\left(\frac{m_u + m_d}{2}\right)}$$

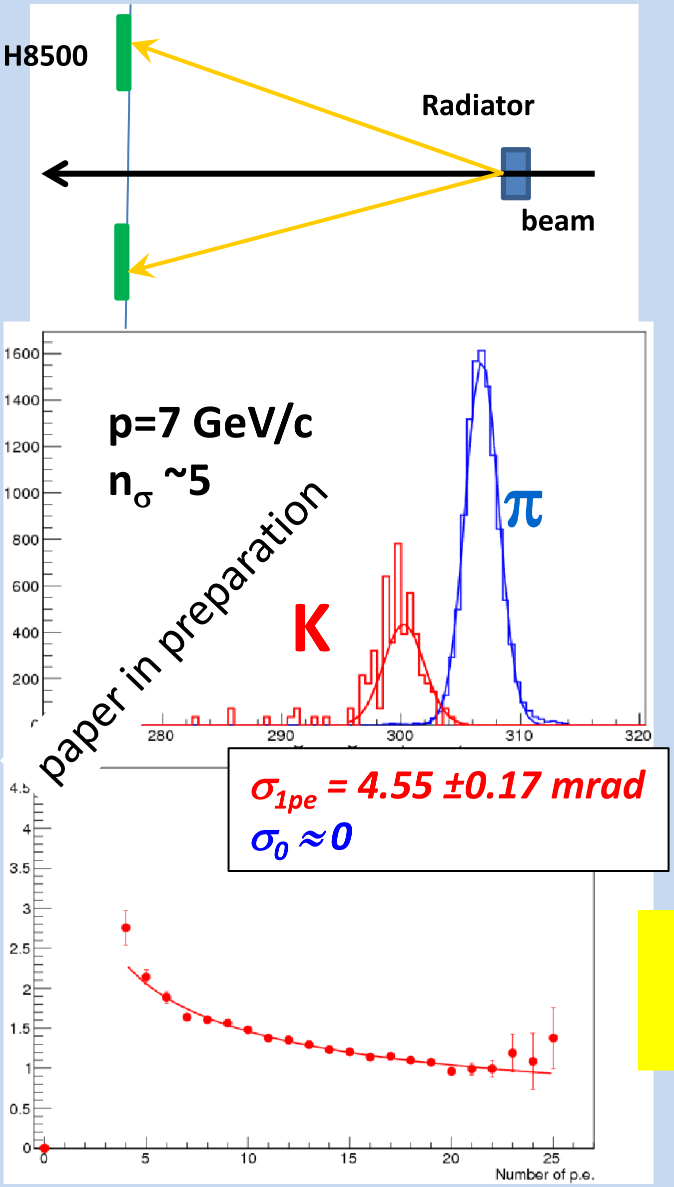


Prototype tests at CERN

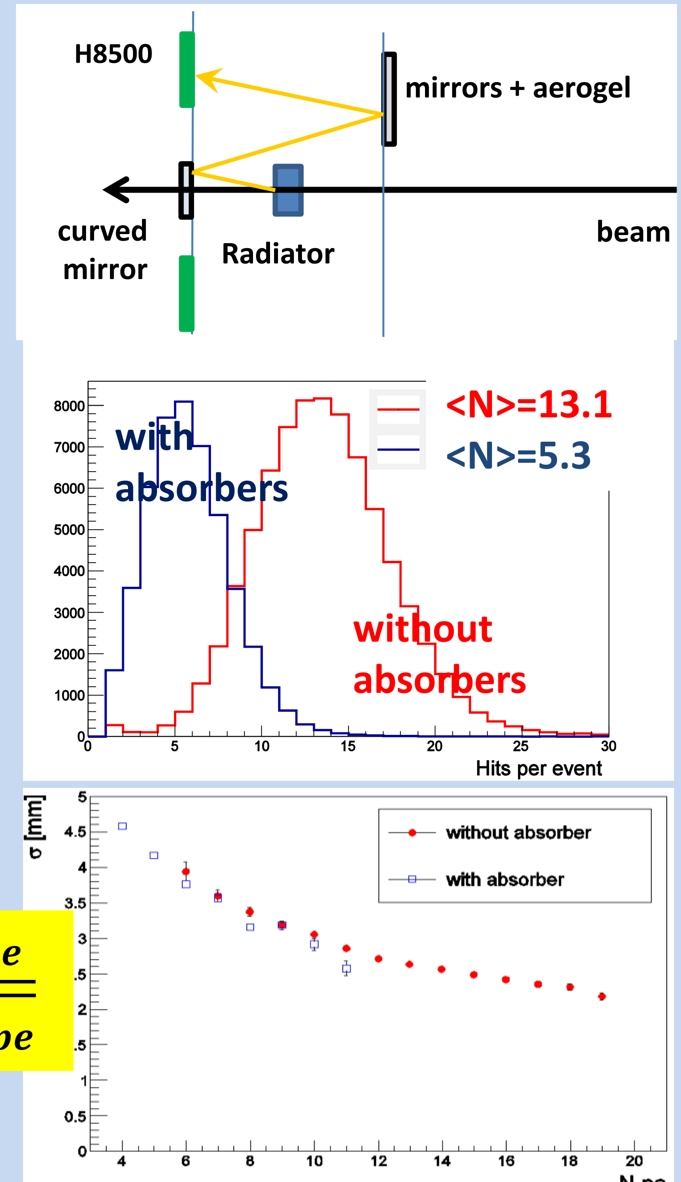


Prototype tests at CERN

direct light



reflected light

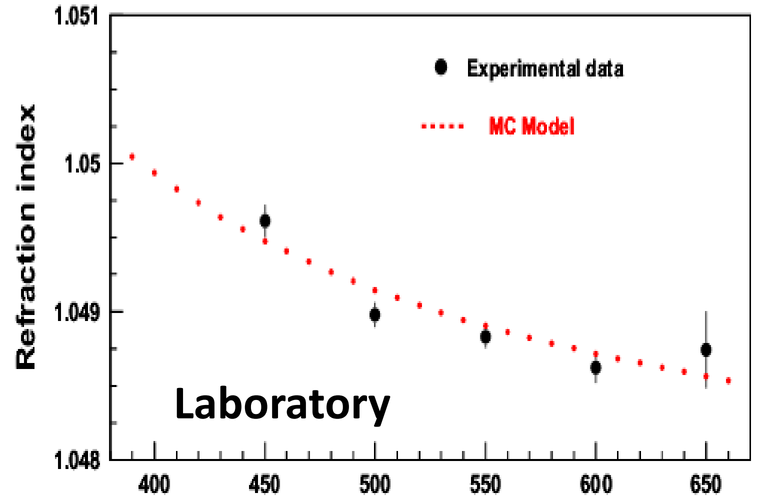


$$\sigma_R = \sigma_0 + \frac{\sigma_{1pe}}{\sqrt{N_{pe}}}$$

Aerogel characterization

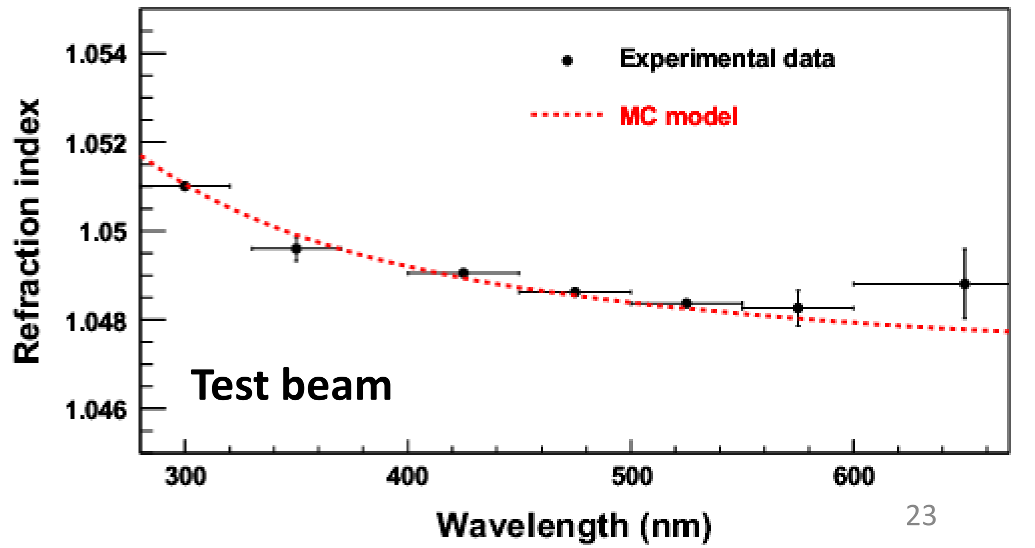
The aerogel produced by BINP (Novosibirsk) has been selected for the RICH

- suitable refractive index: n=1.05
- large tiles: 20x20 cm^2
- high transmittance: > 0.6 at λ=400 nm
- low chromatic dispersion



Chromatic dispersion measurements

- Laboratory: prism method with a spectrophotometer
- Test beam at CERN with 8 GeV/c pions and optical filters



Monte Carlo calculation

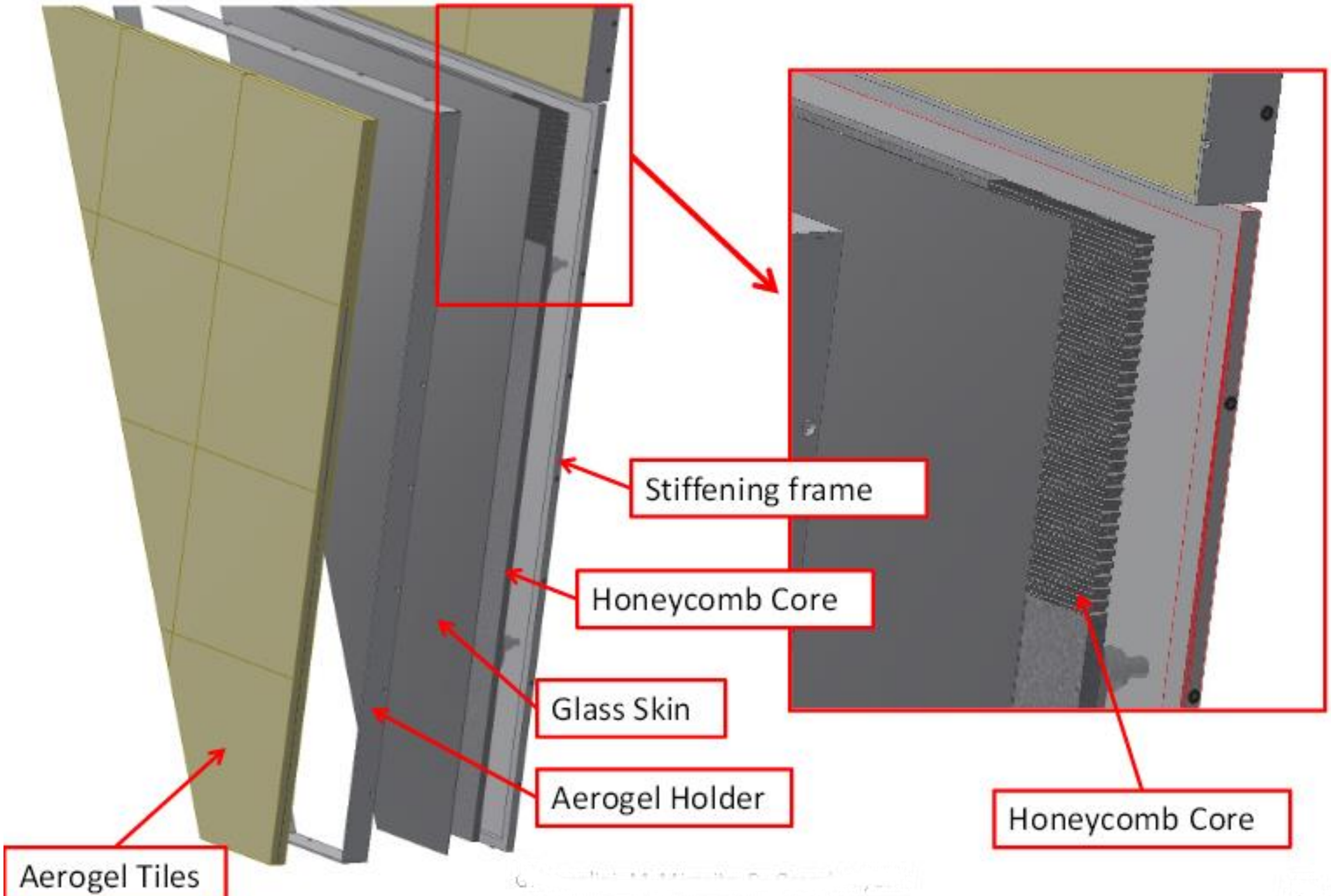
- dispersion model combining air and quartz

The front panel

The front panel holds:

- **the aerogel tiles**
- **the flat mirrors**

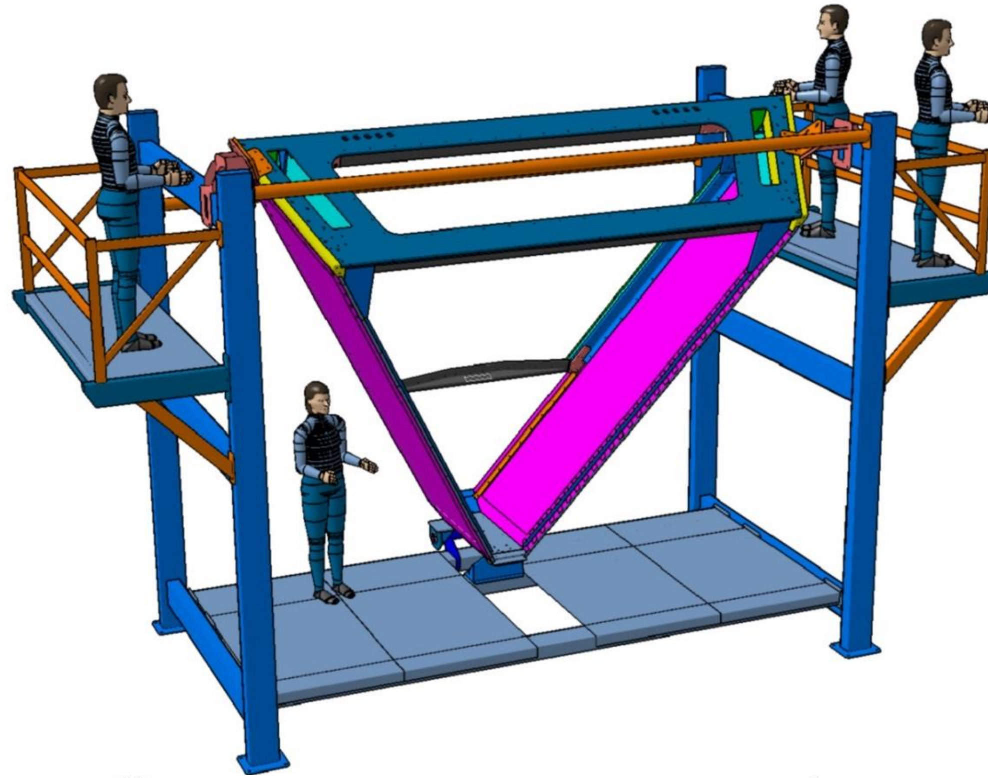
Must be a stiff but light structure
- CFRP skins with honeycomb core

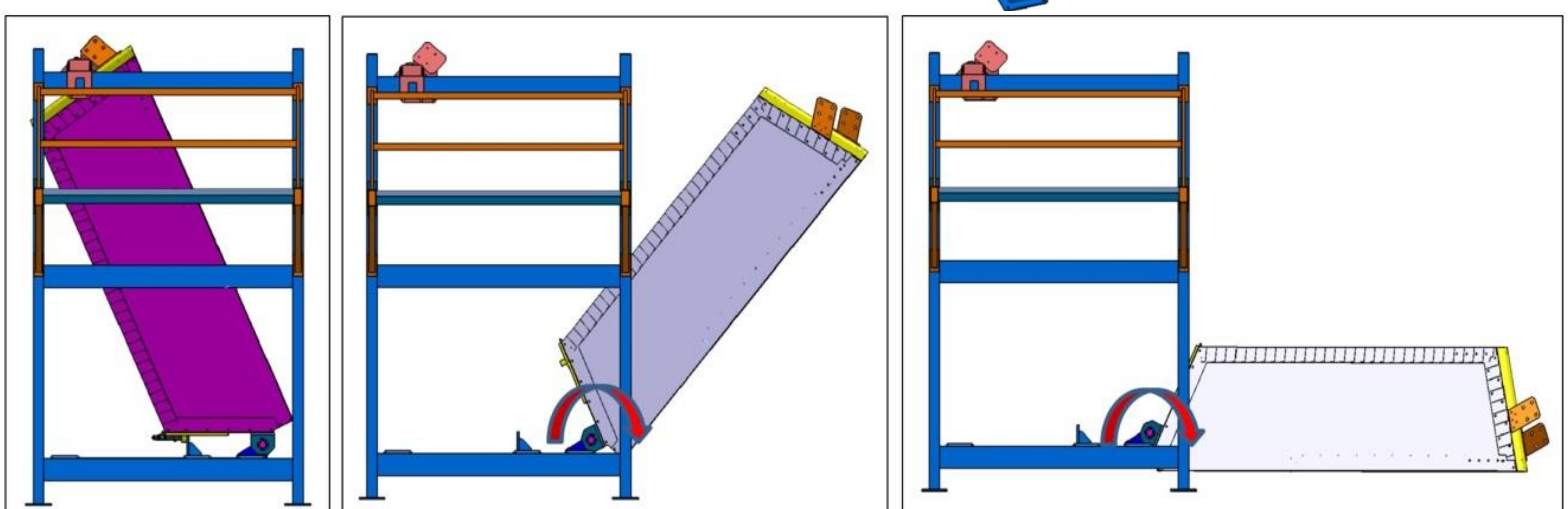


RICH assembly structure

The assembly structure must

- **provide the same attaching point as in CLAS12**
- **allow easy access for the installation of the inner components**
- **allow the smooth handling of the module for transportation in the experimental hall**





RICH installation

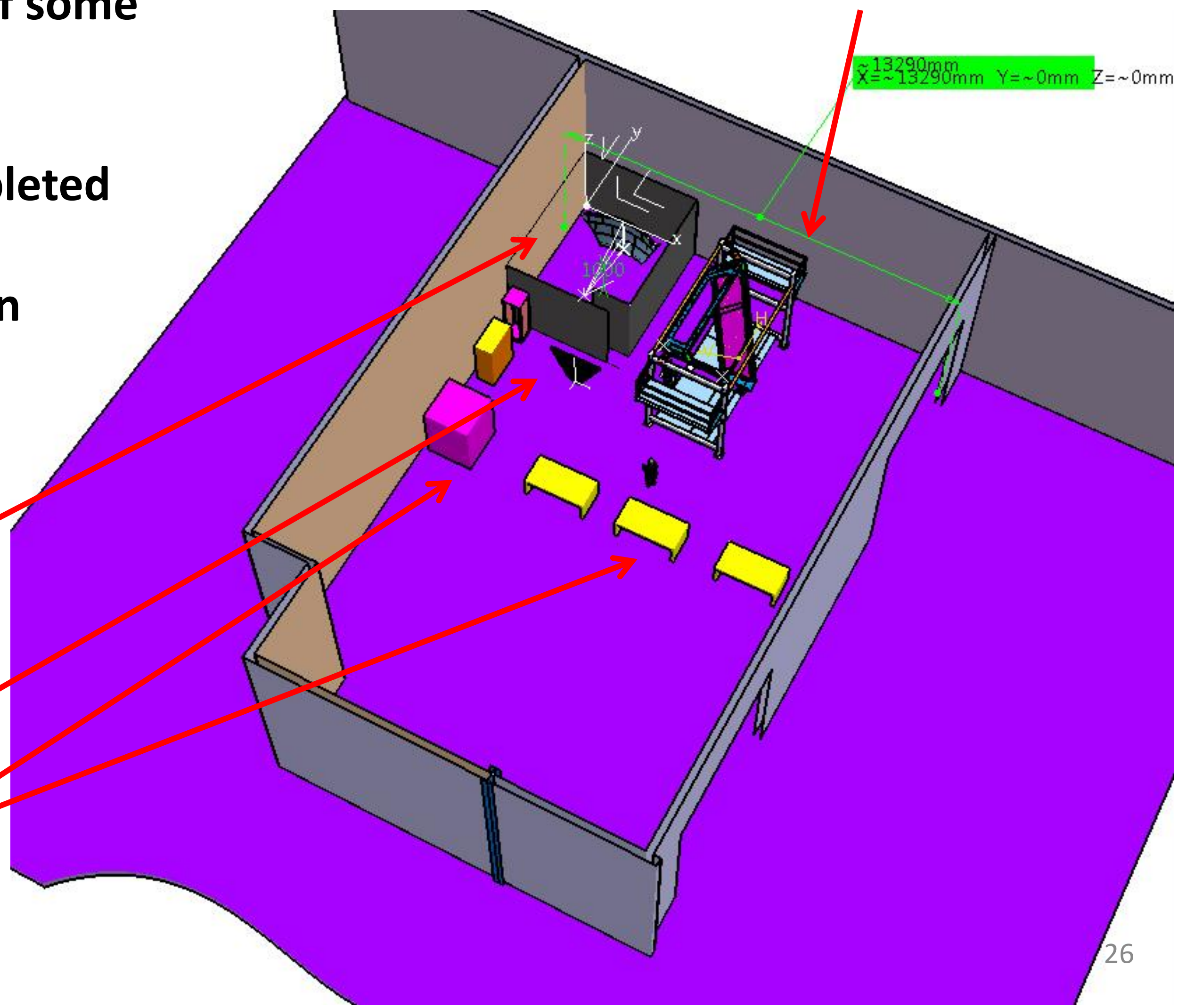
The assembly of the RICH will be performed at JLab in a clean area (aerogel, mirrors)

apr 2016 pre-assembly of some components

oct 2016 RICH module

mar 2017 assembly completed (mirrors)

apr 2017 start installation



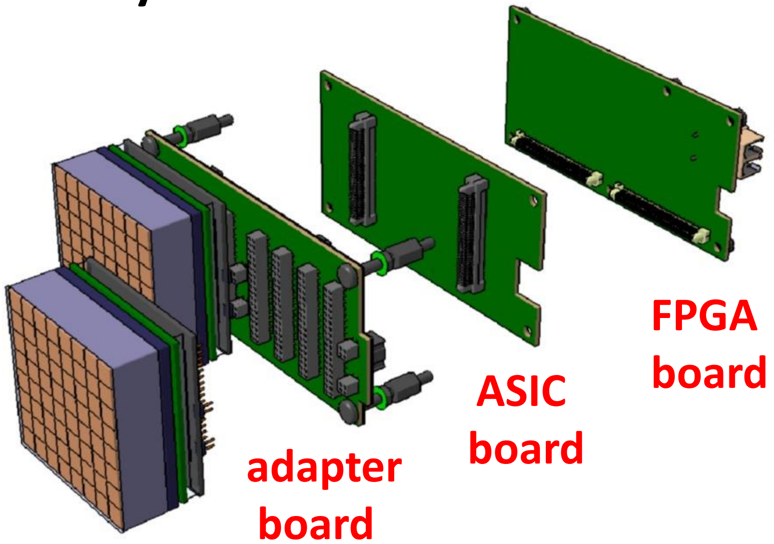
Electronics

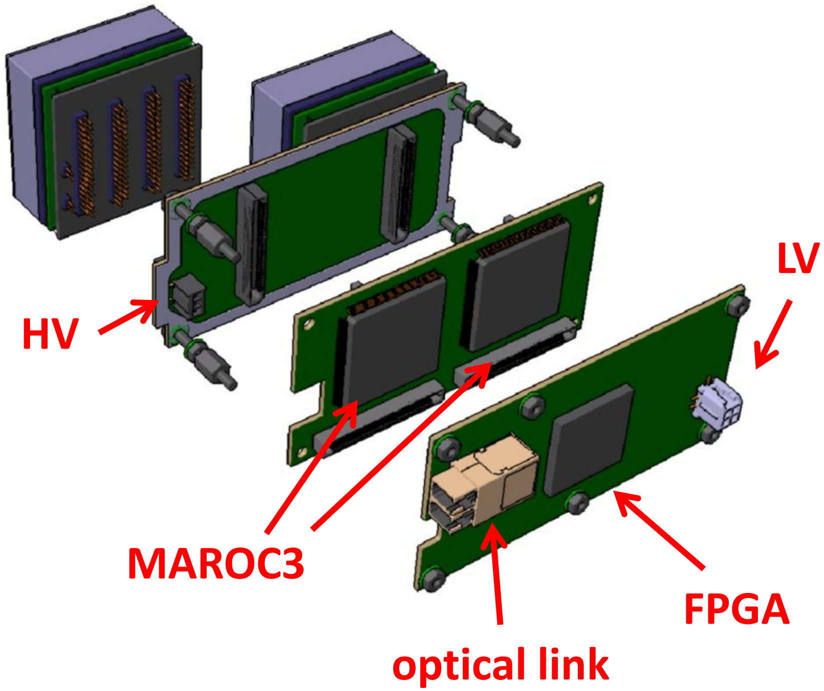
Complex system

- **About 400 MAPMTs, 25000 channels**

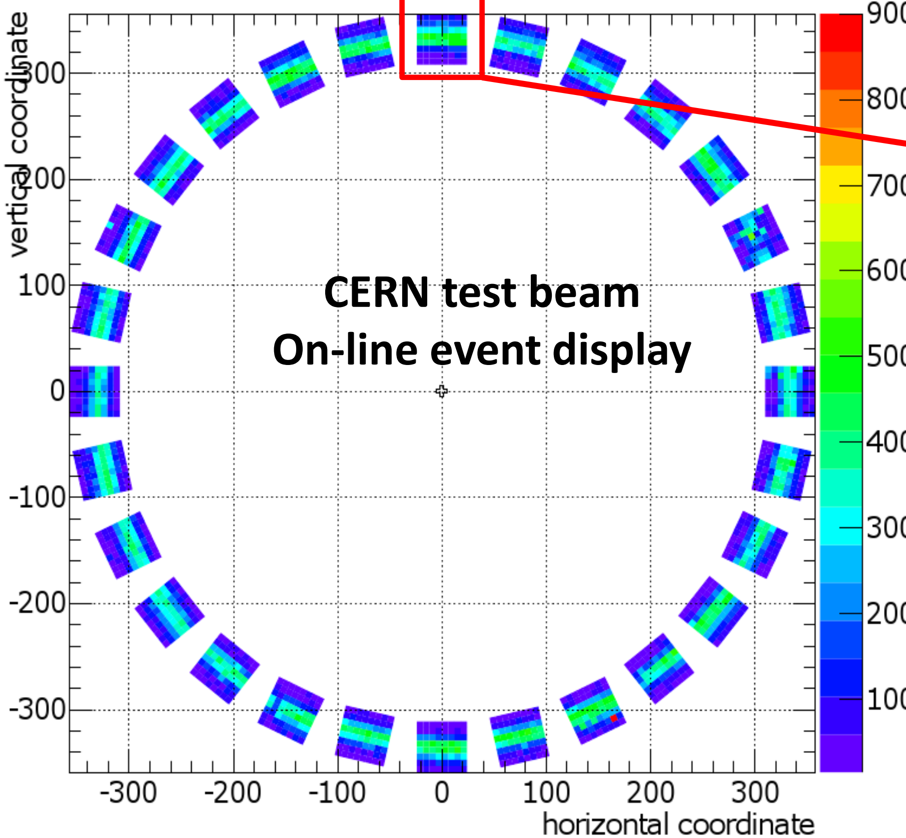
Modular structure

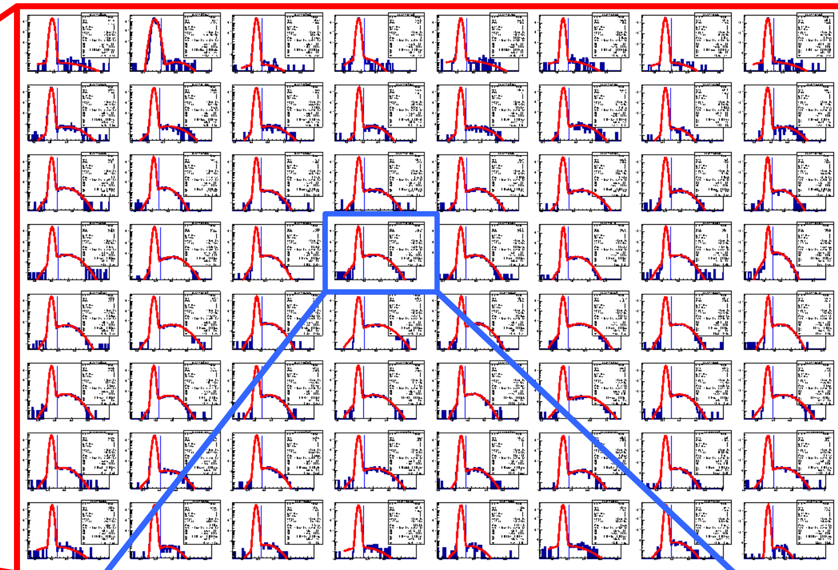
- **Groups of 2 or 3 MAPMT form a tile**
- **Each MAPMT is served by a MAROC3 chip**
- **Each tile is served by LV, HV and an FPGA with optical connection**
- **The tiles are assembled on a supporting panel made by a sandwich of Al and honeycomb**

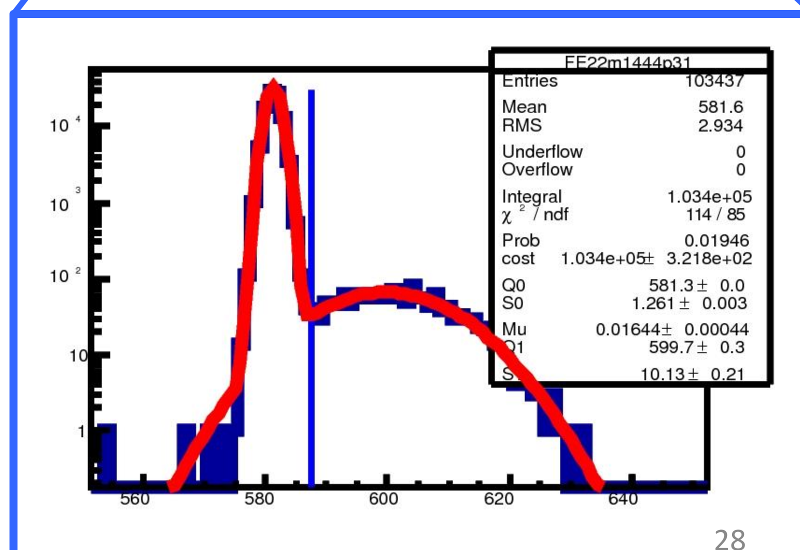




MAPMT & MAROC3







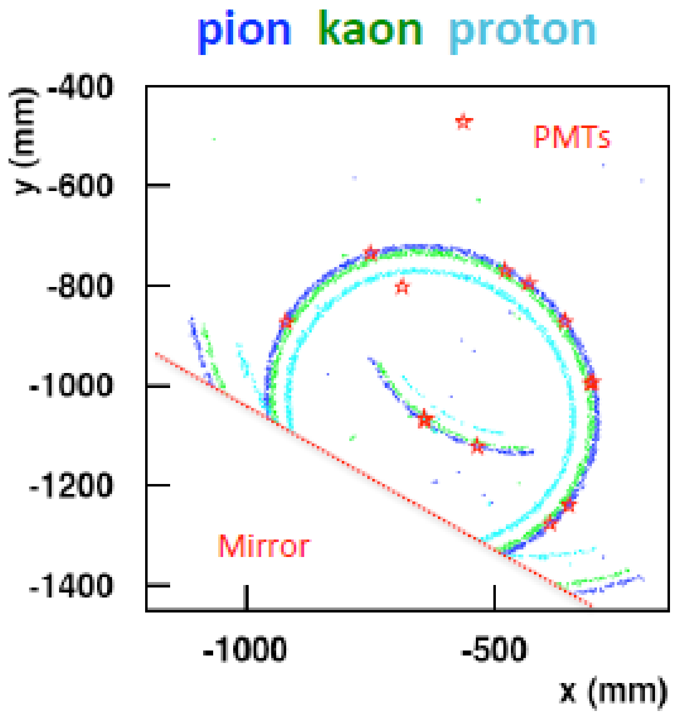
RICH performances

Simulations tuned to CERN data

Direct detection: higher momenta
- rings are closer
- larger Npe allows clean ID

Detection after reflection: lower momenta
- rings are well separated
- lower Npe doesn't affect the ID

P = 6.3 GeV/c θ = 6 degrees R_{QP} = 0.59



P = 3.7 GeV/c θ = 22 degrees R_{QP} = 0.98