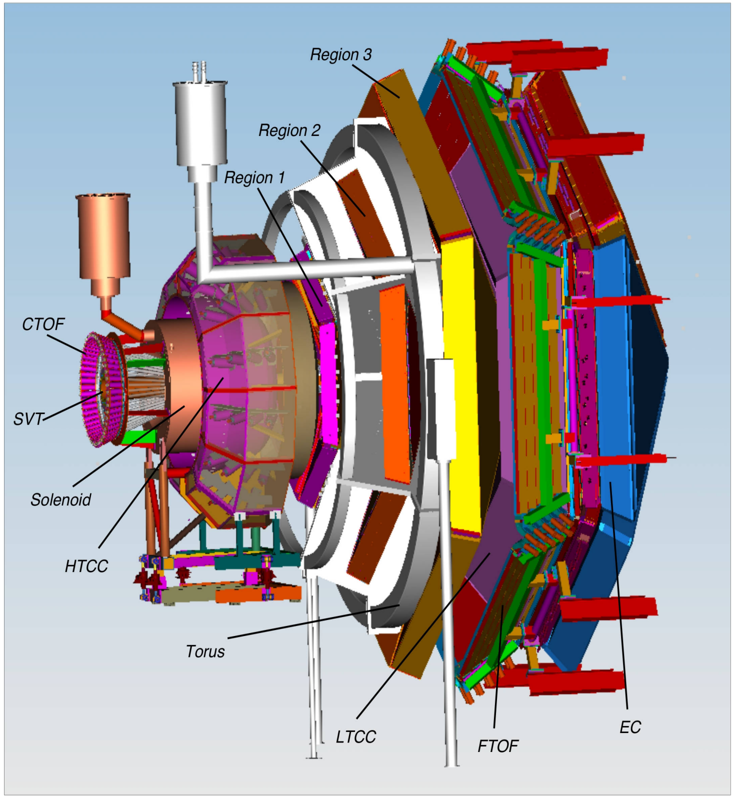
DIRC 2017 International Workshop on Fast Cherenkov Detectors

Photon detection, DIRC design and DAQ

Jefferson Lab
Thomas Jefferson National Accelerator Facility

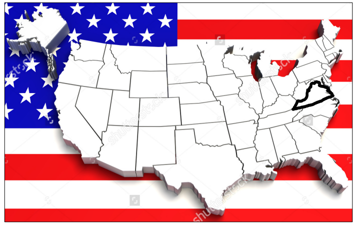
INFN



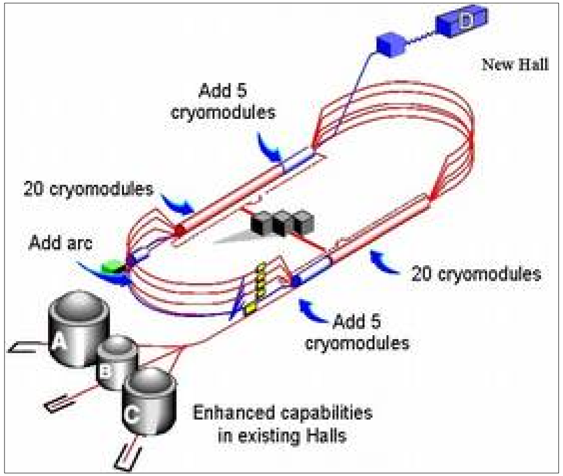
The CLAS12 RICH detector

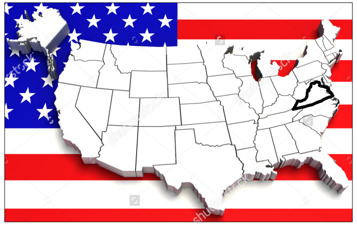
Balossino Ilaria
University and **INFN *Ferrara***
on the behalf on the CLAS12 RICH Group

RICH



Continuous Electron Beam Accelerator Facility





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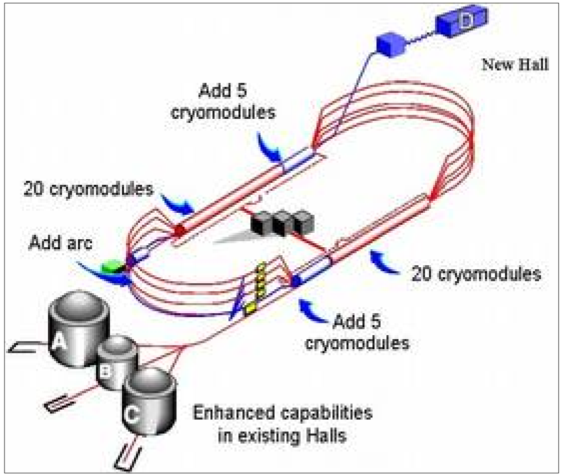
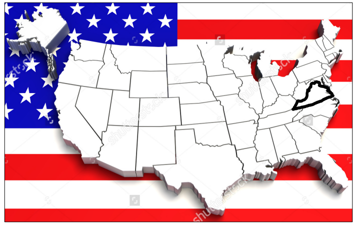
C<u>ontinuous</u> E<u>lectron</u> B<u>eam</u> A<u>ccelerator</u> F<u>acility</u>

- ***Beam Energy 12 GeV***
- ***Beam Intensity 90 μA***
- ***Beam Polarization 85 %***
- ***4 Experimental Halls***





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Thomas Jefferson National Accelerator Facility

Continuous **E**lectron **B**eam **A**ccelerator **F**acility

- ***Beam Energy*** ***12 GeV***
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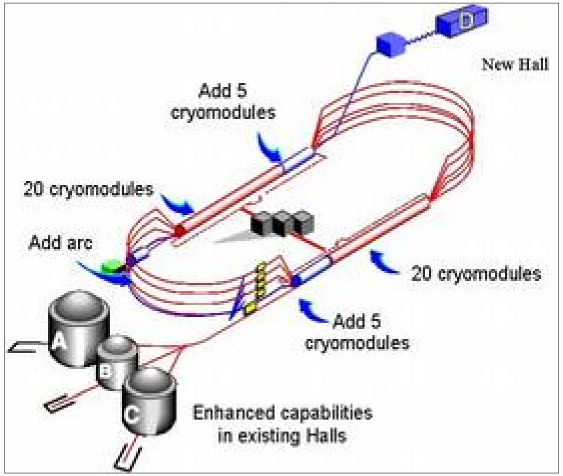
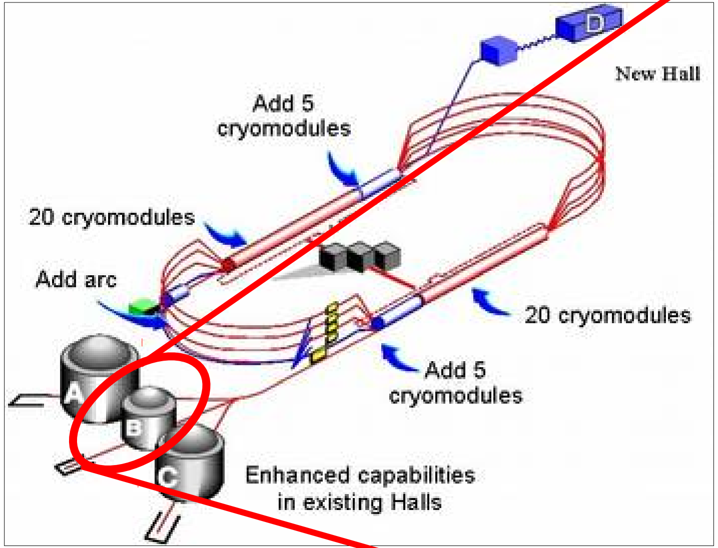
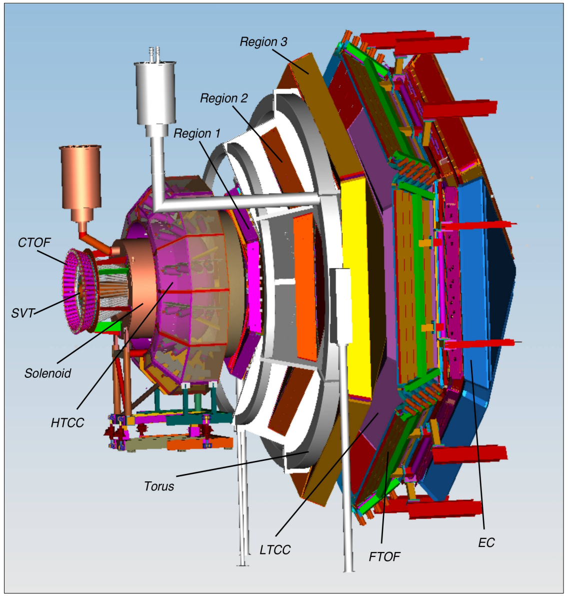


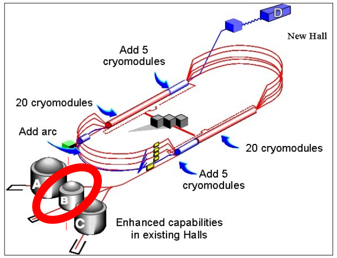
- Hadron Spectra as Probes of QCD
- 3D Structure of Hadrons
- Hadrons in Cold Nuclear Matter
- Transverse and Longitudinal Spin Structure
- Low-energy Tests of the Standard Model and Fundamental Symmetries

CLAS 12

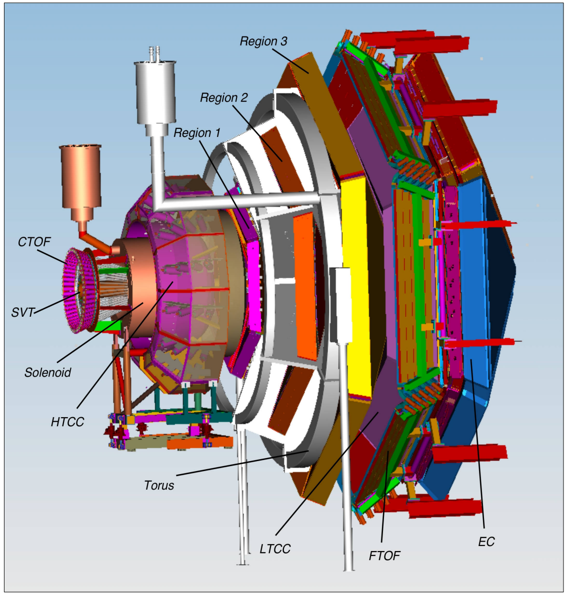


CEBAF
Large Acceptance Spectrometer
12GeV





CLAS 12 Design Overview

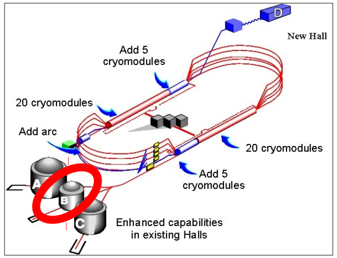


→ Design Luminosity: **10^{35} *cm^{-2} s^{-1}*** ←

→ Longitudinally and Transversely **polarized** H and D **targets** ←

→ Variety of **Nuclear** Targets ←

→ **Wide** acceptance ←



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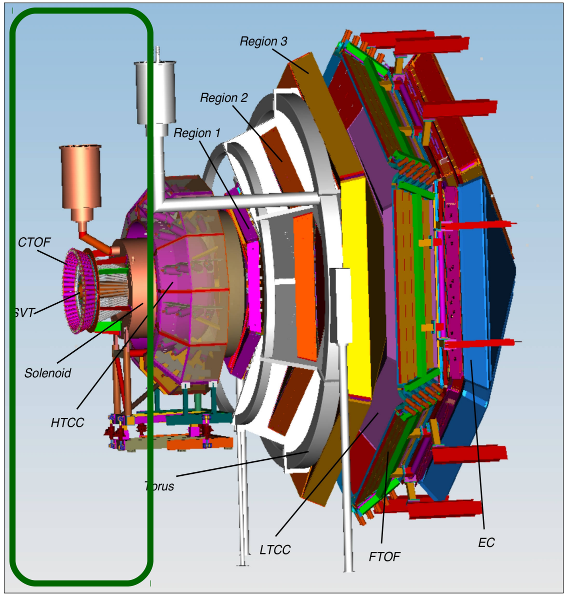

BASELINE EQUIPMENT

Central Detector

$\theta > 40°$

- Solenoidal Field
- Barrel Tracker
- Time-Of-Flight

→ Design Luminosity: **10^{35} *cm^{-2} s^{-1}*** ←

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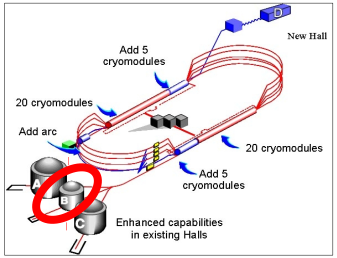

CLAS 12 Design Overview

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BASELINE EQUIPMENT

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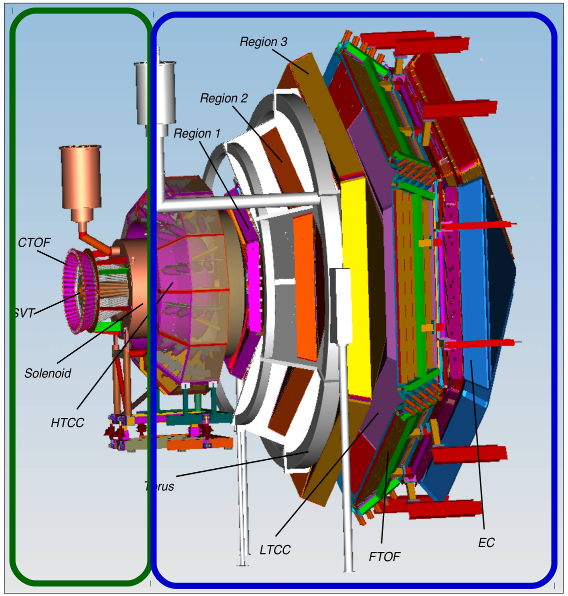

BASELINE EQUIPMENT

Forward Detector

$5° < \theta < 40°$

- Toroidal Field
- Drift Chambers
- Time-Of-Flight
- Threshold Cherenkov Counters
- Preshower and EM Calorimeter

→ Design Luminosity: **10^{35} *cm^{-2} s^{-1}*** ←

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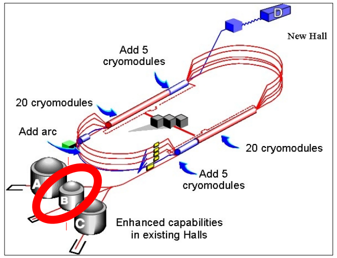
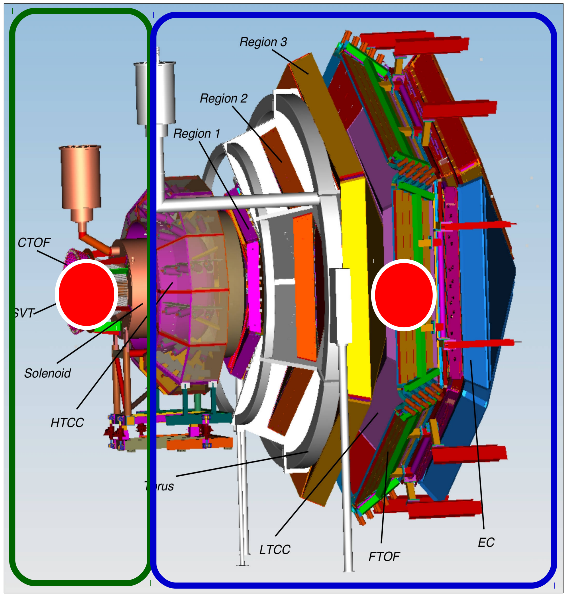


CLAS 12

Design Overview



BASELINE EQUIPMENT

Central Detector

$\theta > 40°$

- Solenoidal Field
- Barrel Tracker
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BASELINE EQUIPMENT

Forward Detector

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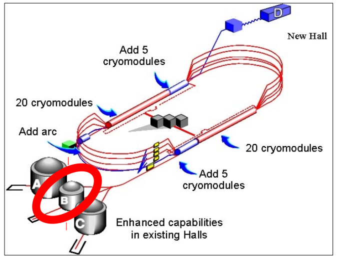
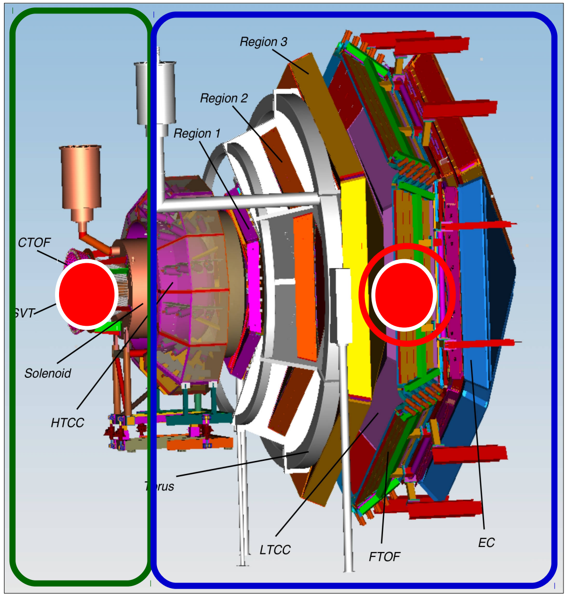
- Toroidal Field
- Drift Chambers
- Time-Of-Flight
- Threshold Cherenkov Counters
- Preshower and EM Calorimeter

Non Baseline Equipment

- Ring-Imaging Cherenkov Detector
- MicroMegas Tracker
- Central Neutron Detector
- Forward Tagger



CLAS 12 Design Overview



BASELINE EQUIPMENT

Central Detector

$\theta > 40°$

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- Barrel Tracker
- Time-Of-Flight

BASELINE EQUIPMENT

Forward Detector

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Non Baseline Equipment

- **Ring-Imaging Cherenkov Detector**
- MicroMegas Tracker
- Central Neutron Detector
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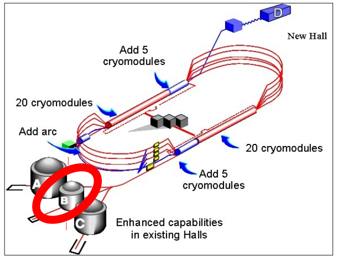
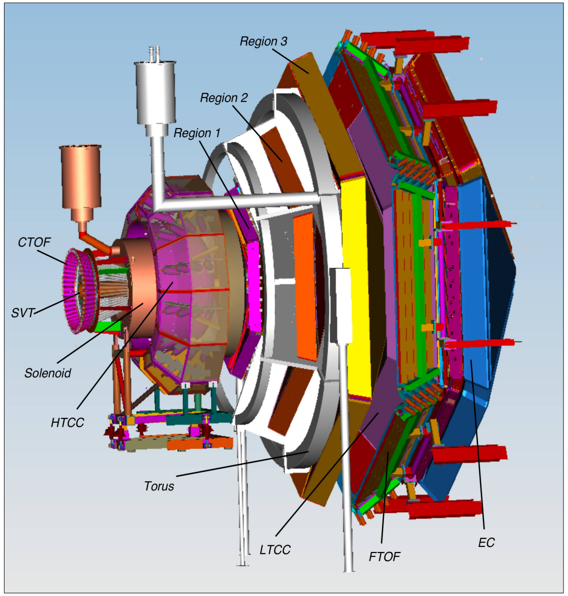


CLAS 12 Physics Program



- 3D Nucleon Image
- Hadronization Process
- Quark Propagation in Nuclear Medium
- Strangeness Distribution
- Exotic Mesons

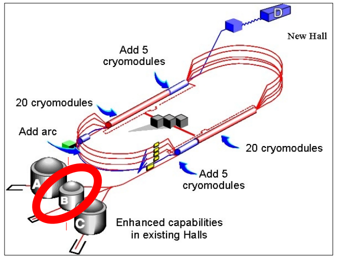
→ **T**ransverse **M**omentum **D**ependence **D**istributions

Semi-**I**nclusive **D**eep **I**nelastic **S**cattering ←

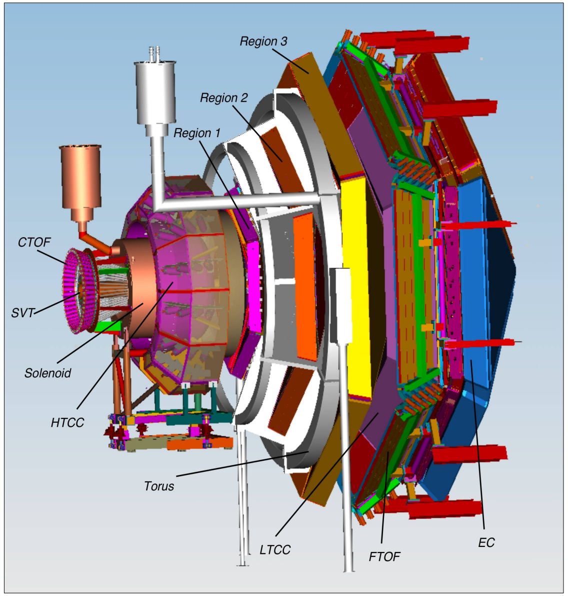
→ **G**eneral **P**arton **D**istribution **F**unctions

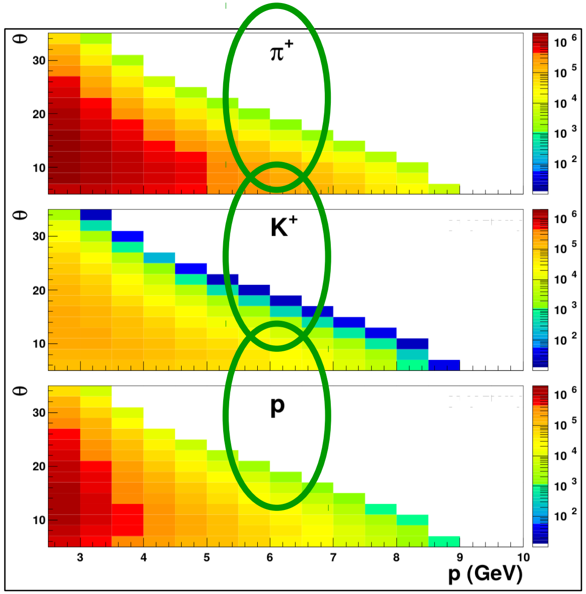
Deep **V**irtual **C**ompton **S**cattering ←

Deep **V**irtual **M**esons **P**roduction ←



CLAS 12 *Physics Program*





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Semi-**I**nclusive **D**eep **I**nelastic **S**cattering ←

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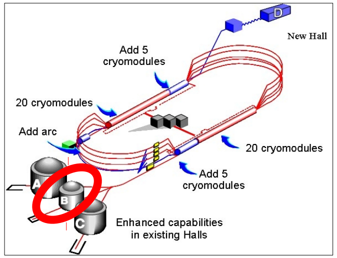

CLAS 12 *Physics Program*

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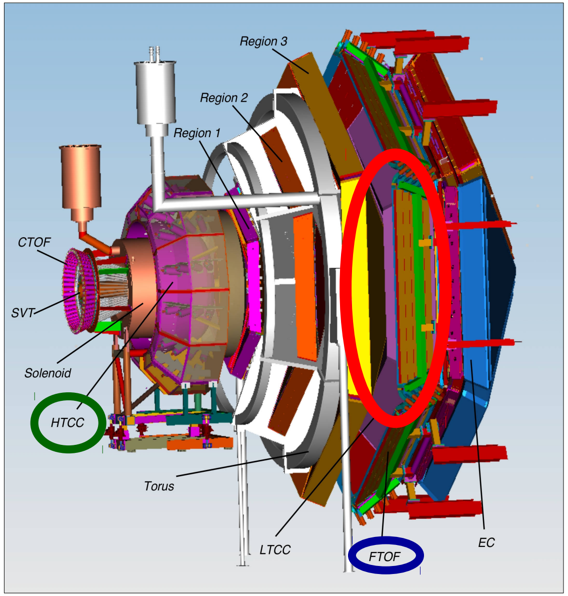

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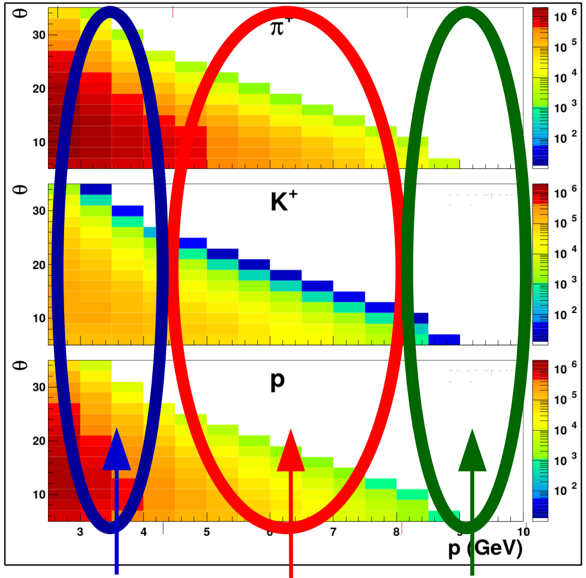

FTOF

HTCC

→ **T**ransverse **M**omentum **D**ependence **D**istributions
→ **S**emi-**I**nclusive **D**eep **I**nelastic **S**cattering ←

→ **G**eneral **P**arton **D**istribution **F**unctions
Deep **V**irtual **C**ompton **S**cattering ←
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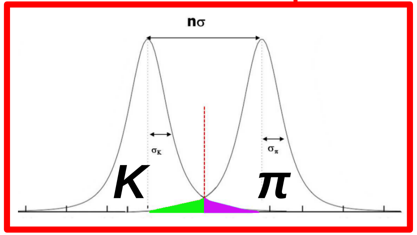
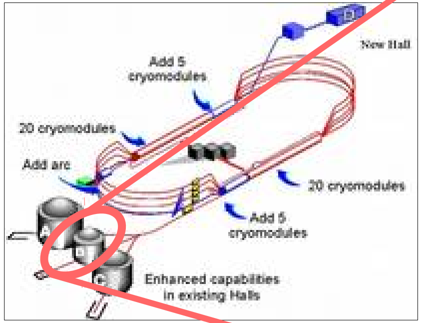
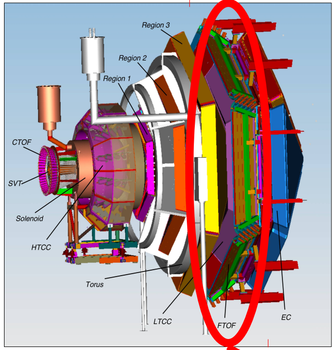


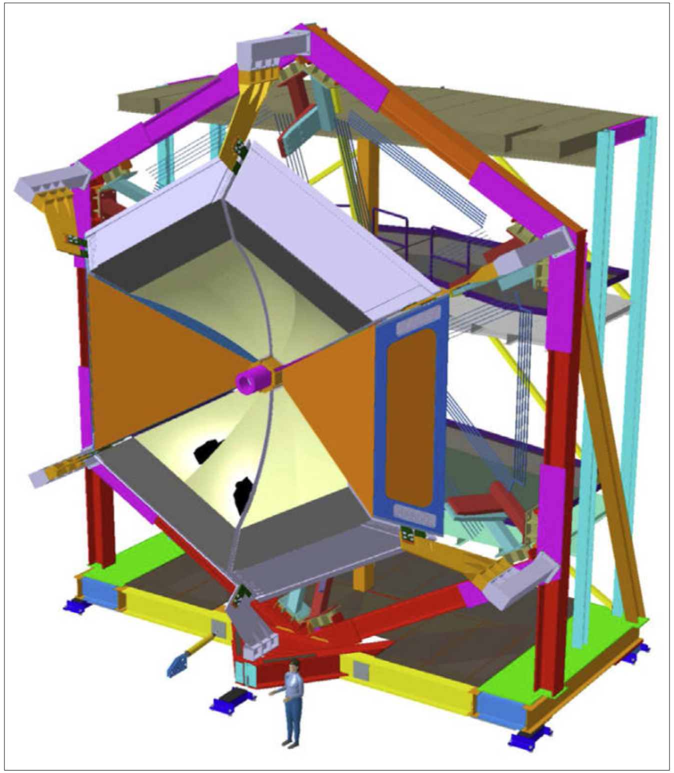
RICH
12GeV upgrade

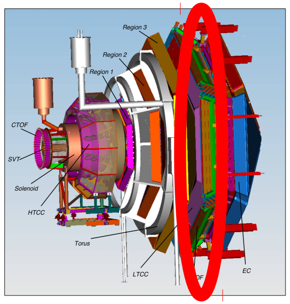


CEBAF
Large Acceptance Spectrometer
12GeV



Ring-Imaging
Cherenkov Detector





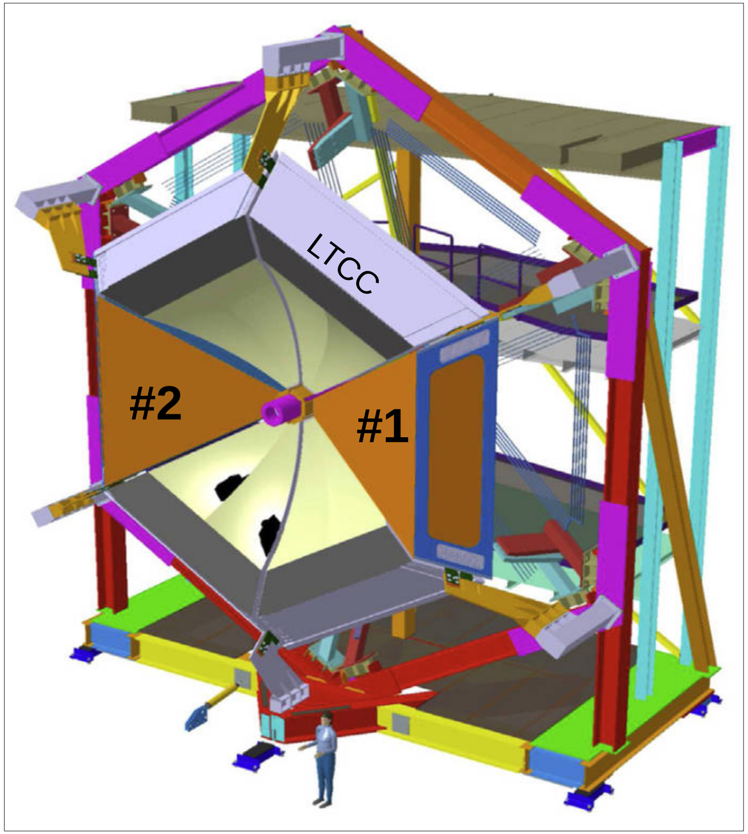
General Layout

#1 Physics with **un-polarized** and **longitudinally polarized** target

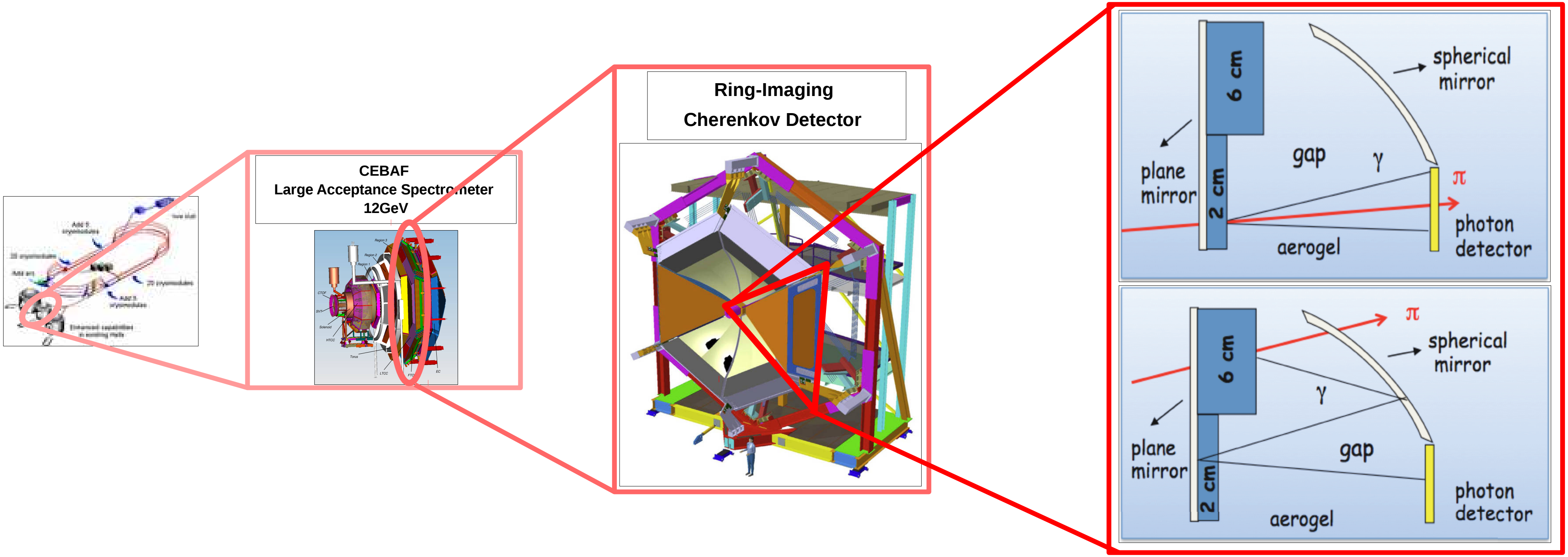
Fall 2017

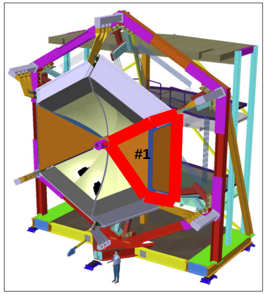
<u>Extend</u> the **kinematical** coverage and <u>control</u> <u>sistematic effects</u> in **polarized target** **#2**

2020

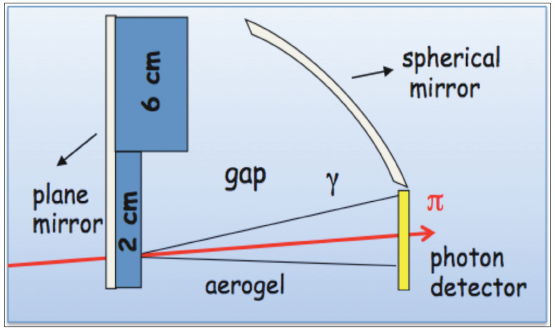


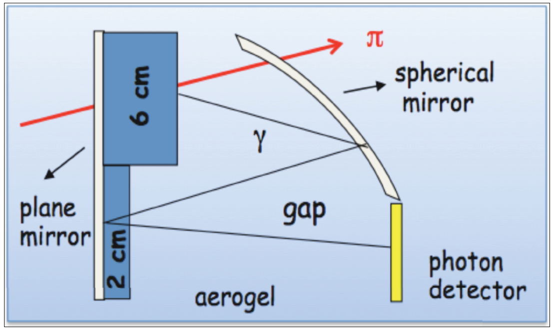
INFN	
	Bari, Ferrara, Genova, Frascati, Roma/ISS, ITA
Jefferson Lab	
	Newport News, USA
Argonne National Lab	
	Argonne, USA
Duquesne University	
	Pittsburg, USA
George Washington University	
	Washington, USA
Glasgow University	
	Glasgow, UK
Kyungpook National University	
	Daegu, KR
University of Connecticut	
	Storrs, USA
UTFSM	
	Valparaiso, Chile


CEBAF
Large Acceptance Spectrometer
12GeV
Ring-Imaging
Cherenkov Detector
6 cm
2 cm
plane mirror
gap
γ
π
spherical mirror
photon detector
aerogel
π
6 cm
spherical mirror
γ
plane mirror
gap
2 cm
photon detector
aerogel



RICH Hybrid Design





- Small Polar Angle (up to 8 *GeV/c*)
- **1 *m*** gap
- **Thin** Aerogel
- **Direct** Imaging of the Cherenkov Photons

- Large Polar Angle (up to 6 *GeV/c*)
- **3 *m*** Path Length
- **Thick** Aerogel to Compensate Photon Loss
- **Reflected** Imaging of the Cherenkov Photons

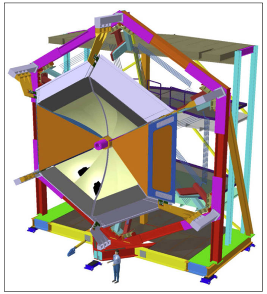
→ Minimize active area (cost) to about **1 m^2** ←

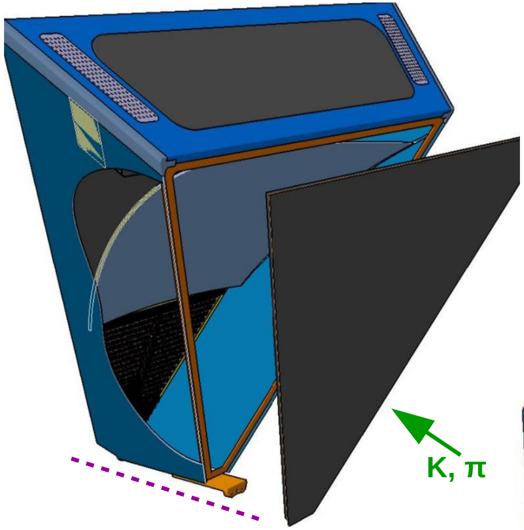
→ Material budget concentrated where **TOF is less effective** ←

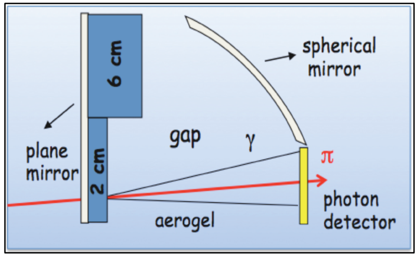
→ **Focalizing mirrors** allow thick radiator for good light yield ←

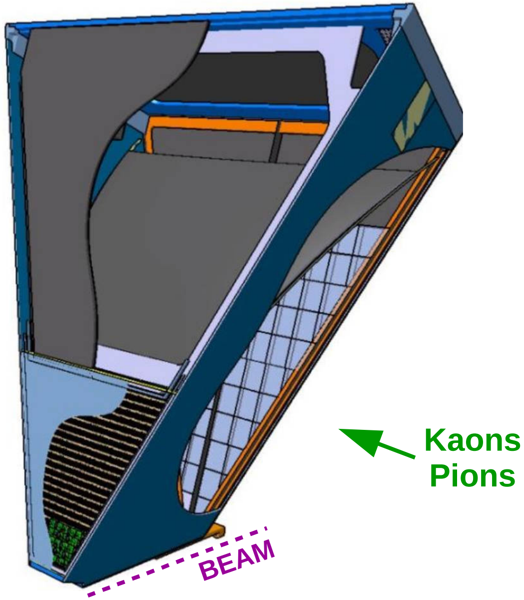
→ Time resolution < **1 *ns*** to distinguish direct and reflected patterns ←

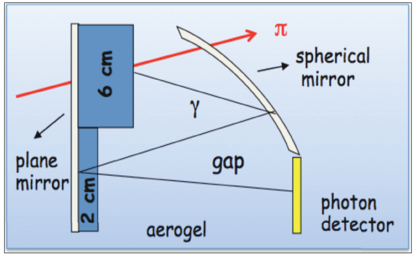
RICH Hybrid Design

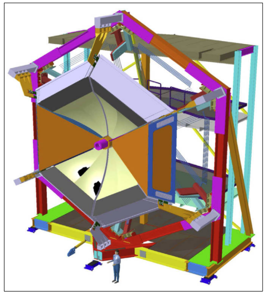




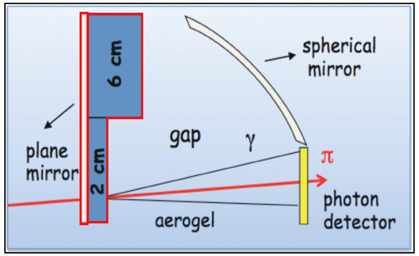


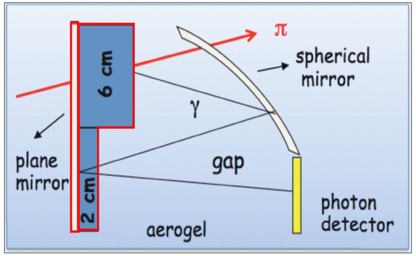


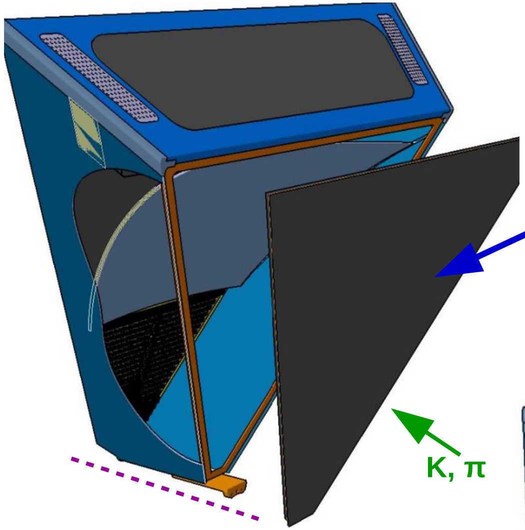




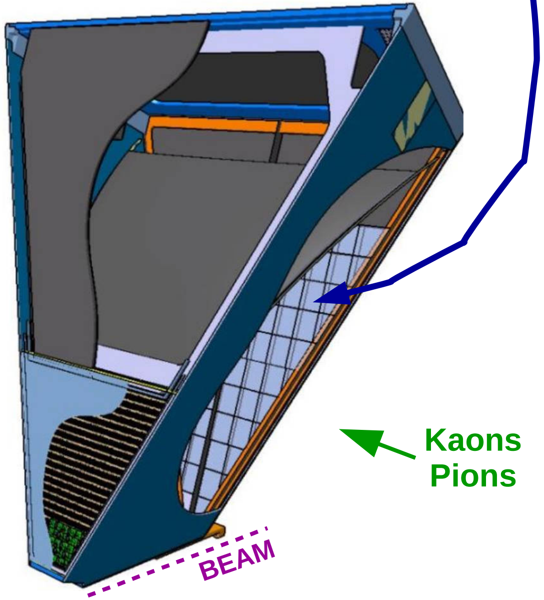
Hybrid Design



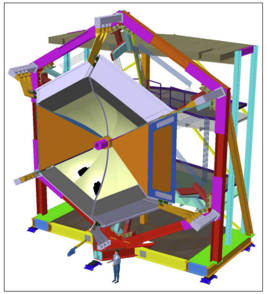


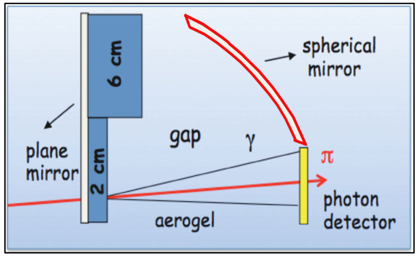


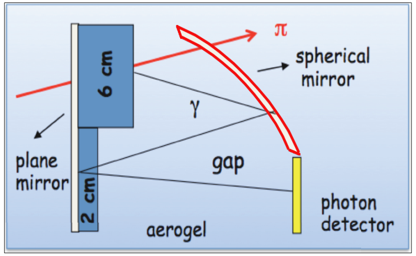
AEROGEL RADIATORS
and
PLANAR MIRRORS

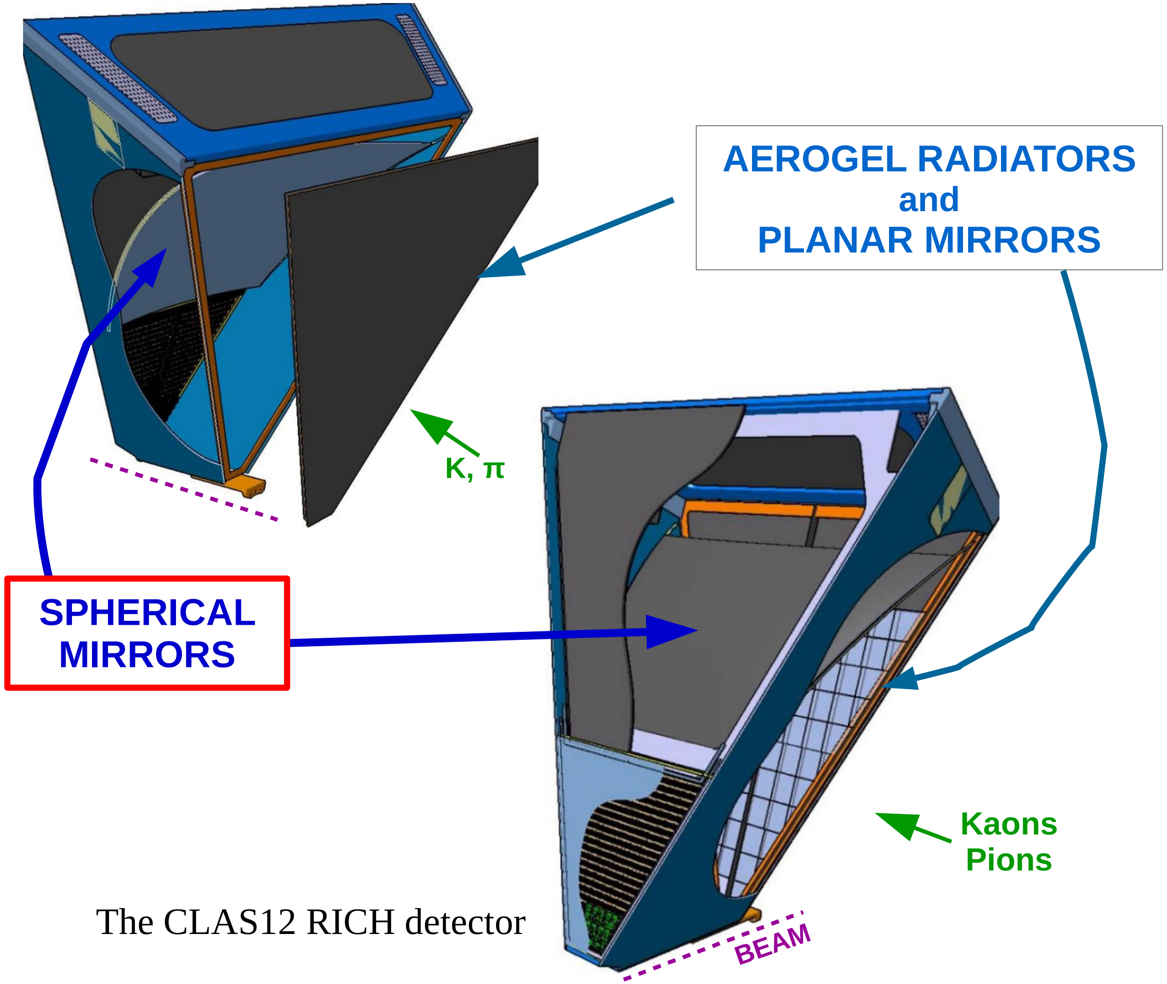


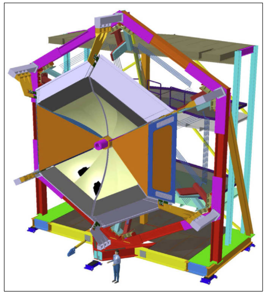
RICH Hybrid Design



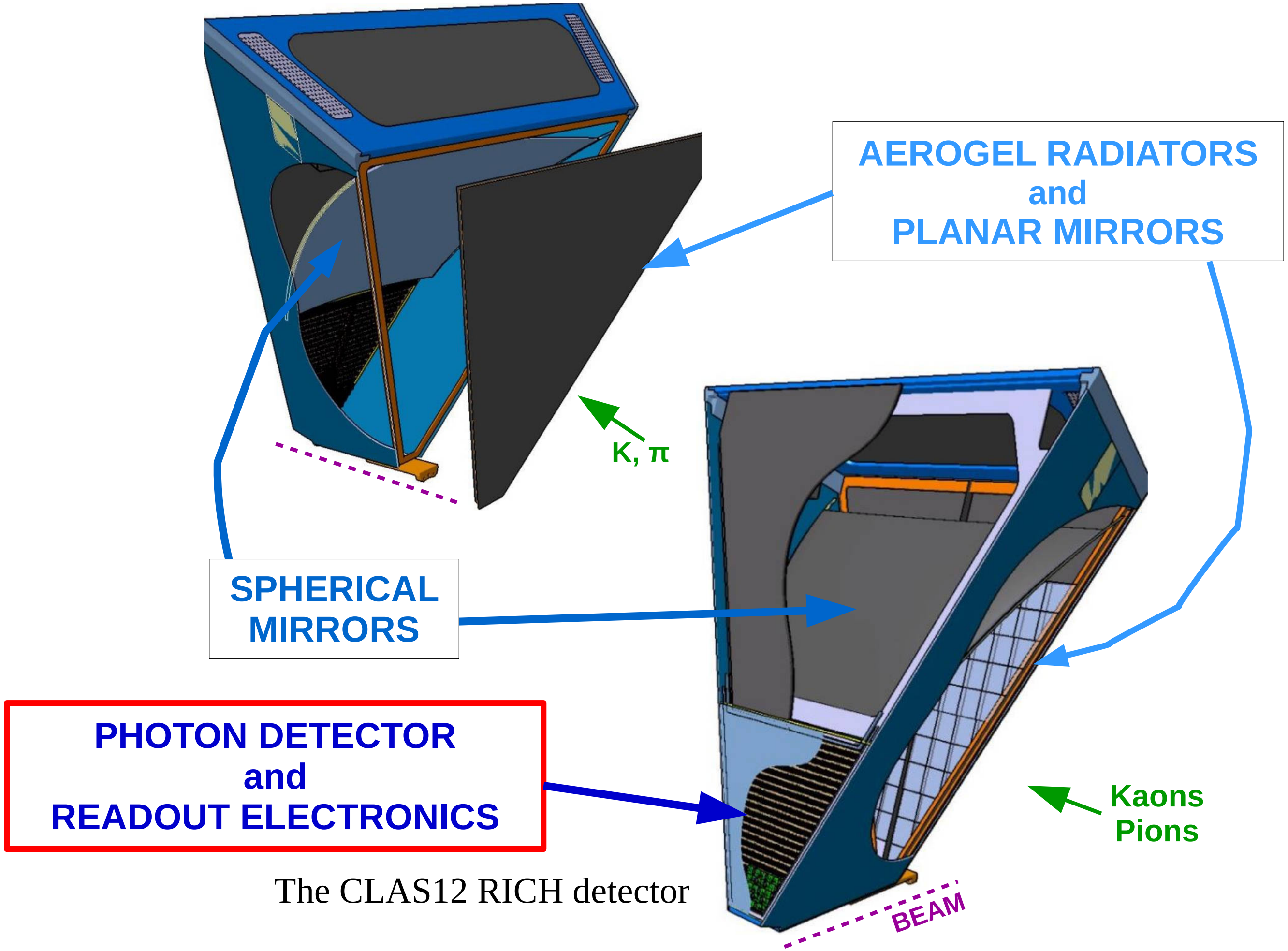


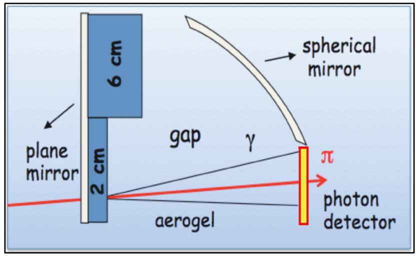


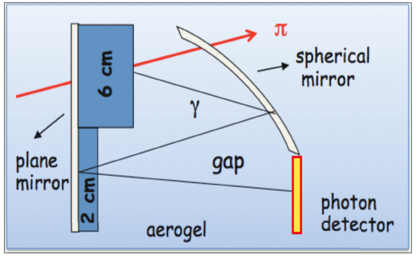




Hybrid Design







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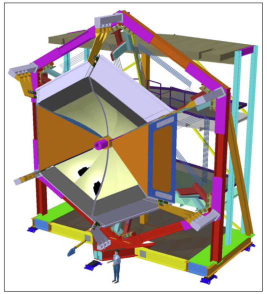
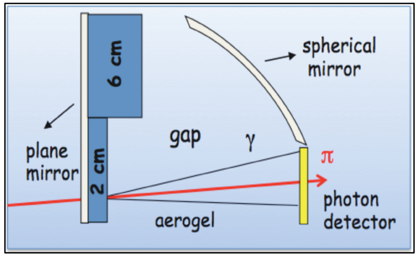
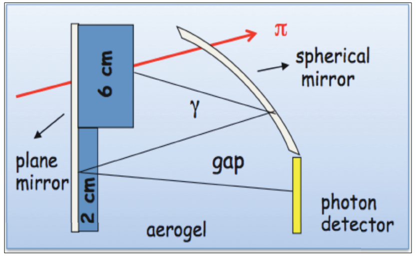
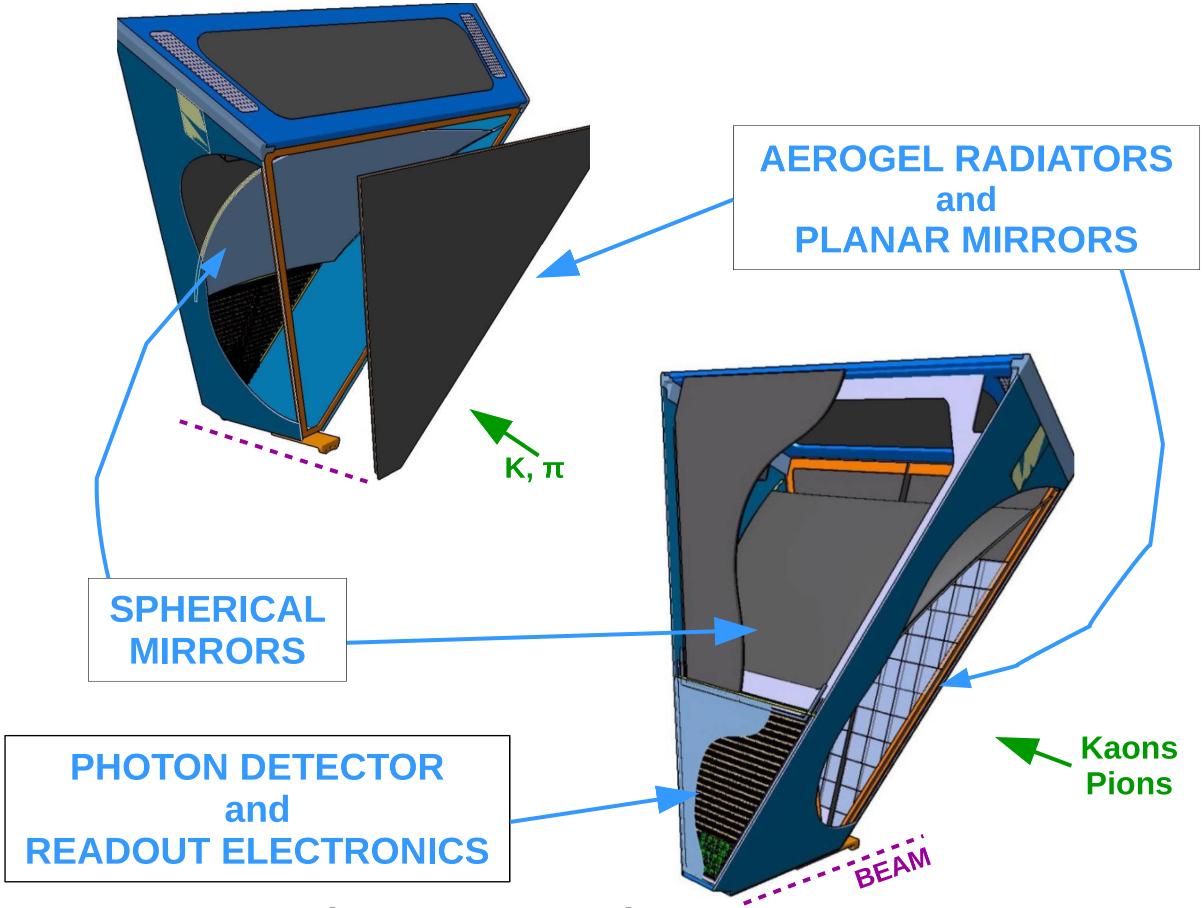
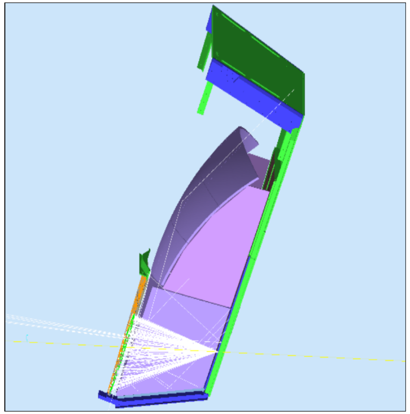
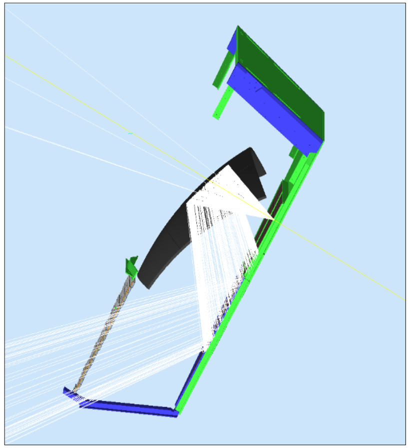


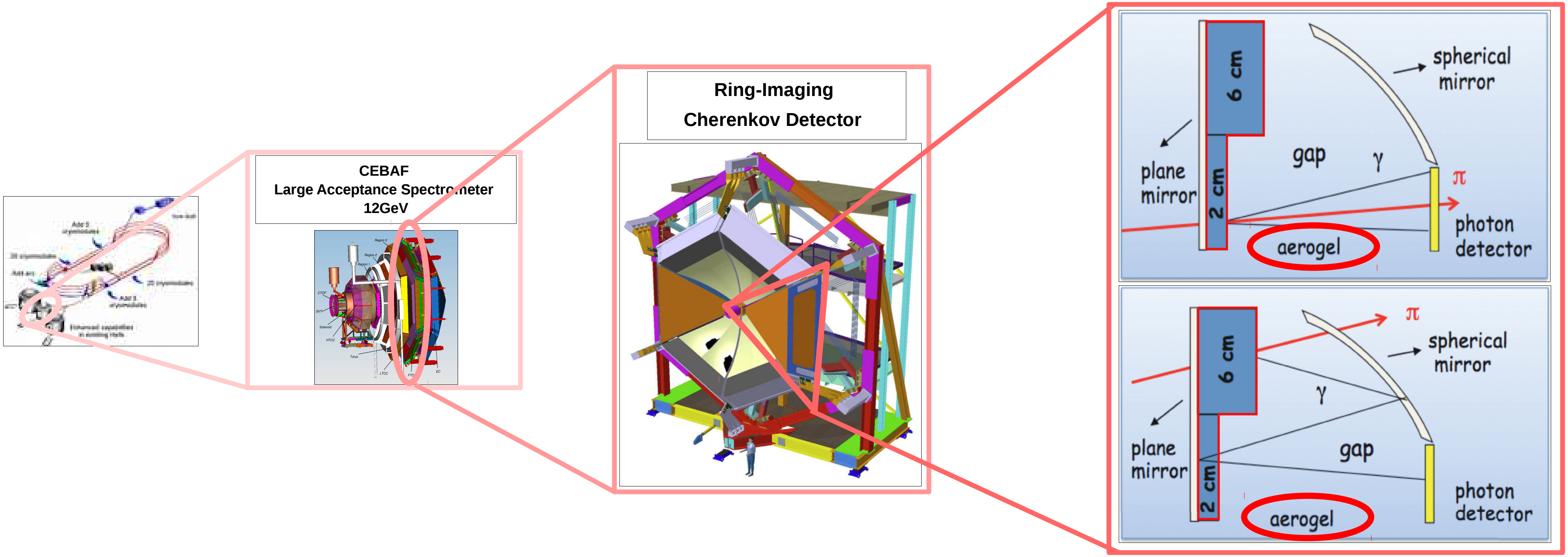




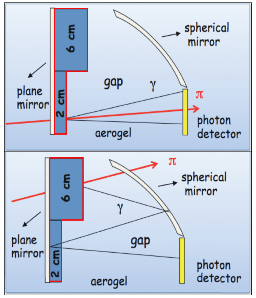








CEBAF
Large Acceptance Spectrometer
12GeV
Ring-Imaging
Cherenkov Detector
6 cm
2 cm
spherical
mirror
plane
mirror
gap
γ
π
photon
detector
aerogel
6 cm
2 cm
π
spherical
mirror
γ
plane
mirror
gap
photon
detector
aerogel

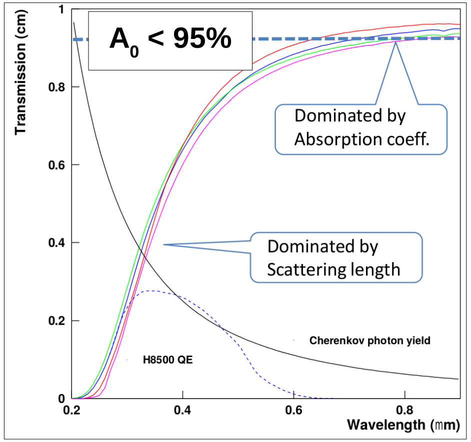


Aerogel in collaboration with Budker and Boreskov Institutes of Novosibirsk (Russia)

REQUIREMENTS:

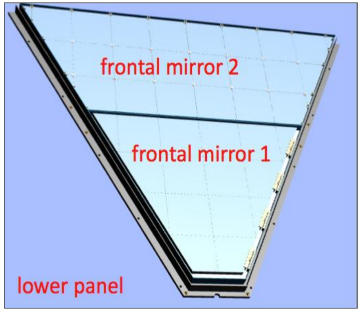
- **High** Transparency
- **Large** Refractive Index

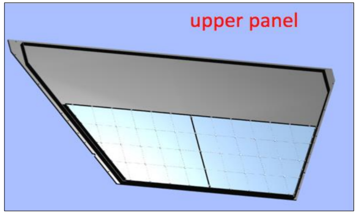
to collect a sufficient number of photons for a reliable ring reconstruction

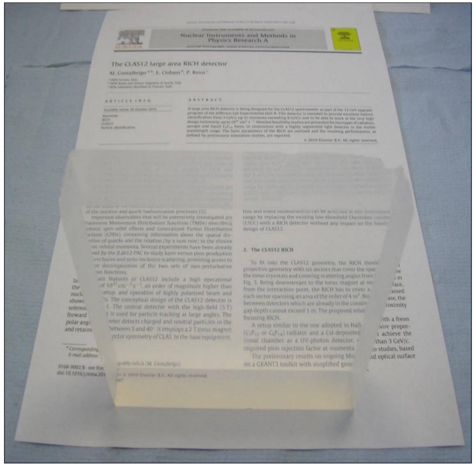


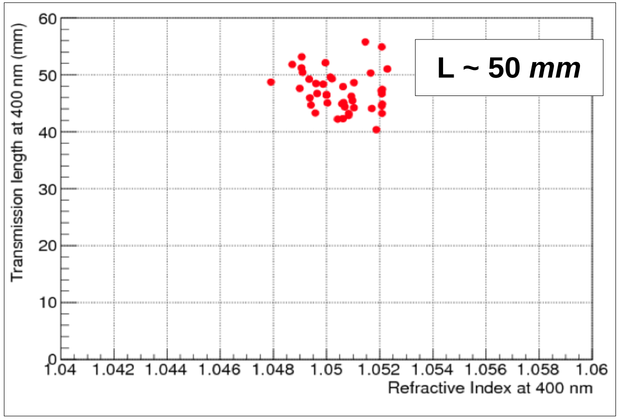
Large area **20 x 20 cm²**
to reduce losses at the edges

n = 1.05



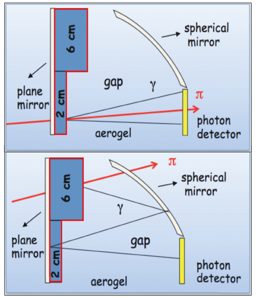




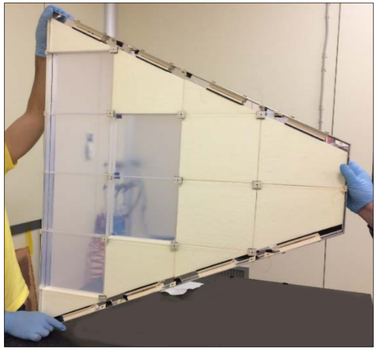


Full **SQUARED**: 72 *(**3 cm** thick)*
22 *(**2 cm** thick)*

SHAPED: 30 tiles



Aerogel in collaboration with Budker and Boreskov Institutes of Novosibirsk (Russia)



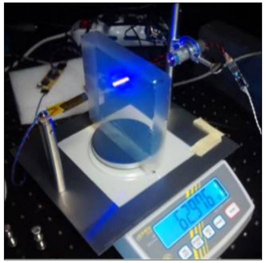
→ **Mechanical** Performance : **COMPRESSION TESTING MACHINE**

→ **Optical** Performance : **SPECTROPHOTOMETER**

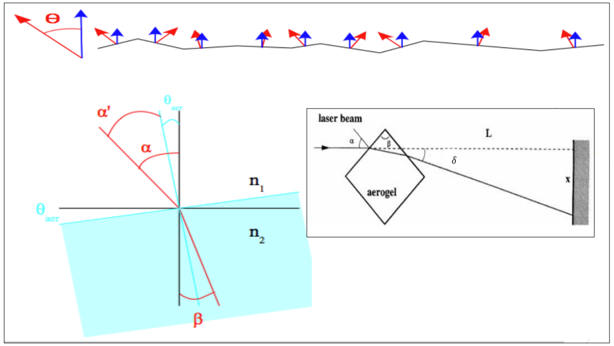
→ **Chromatic** Dispersion : **SPECTROPHOTOMETER + TEST BEAM**

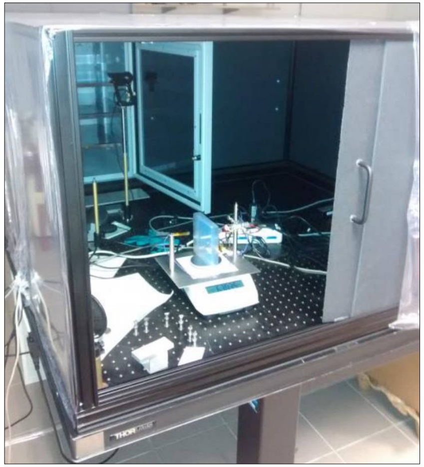
→ Surface **Properties** : **LASER BEAM REFLECTION and REFRACTION STUDIES**

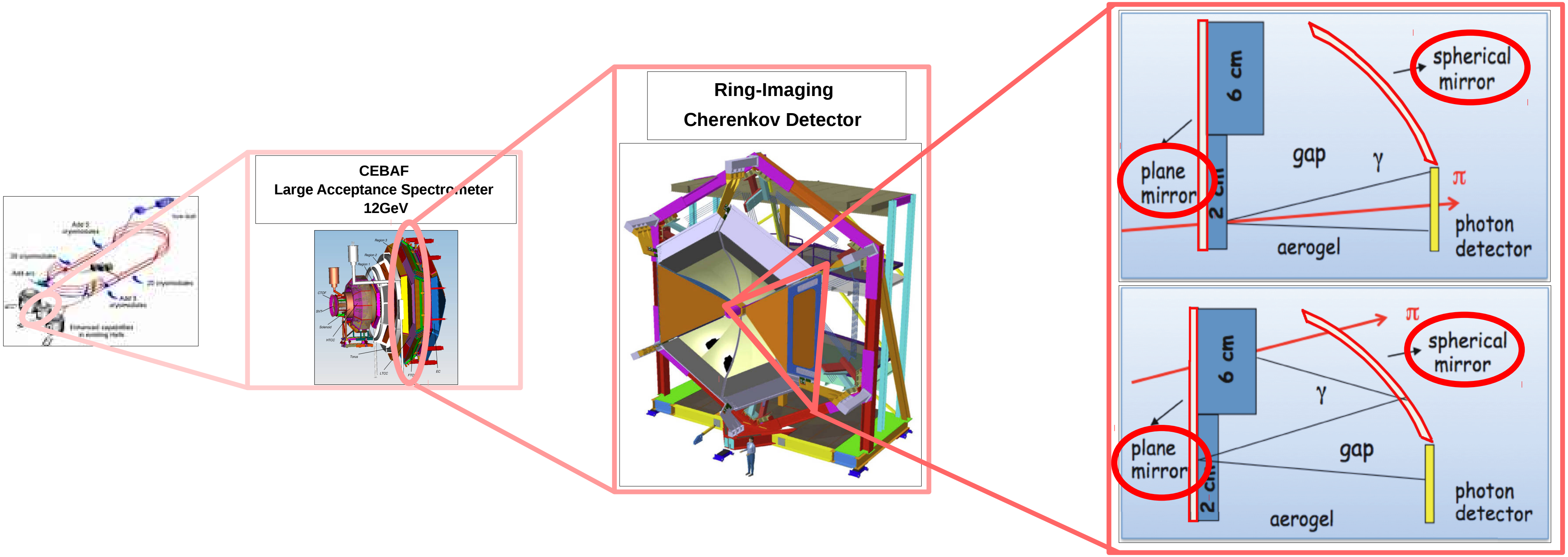
<u>Aerogel production</u> for CLAS12 RICH is expected to be **completed** in **August 2017**



Non invasive <u>techniques</u> employed






CEBAF
Large Acceptance Spectrometer
12GeV
Ring-Imaging
Cherenkov Detector
6 cm
2 cm
spherical mirror
plane mirror
gap
γ
π
photon detector
aerogel
6 cm
2 cm
π
spherical mirror
γ
plane mirror
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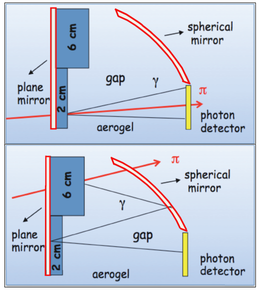
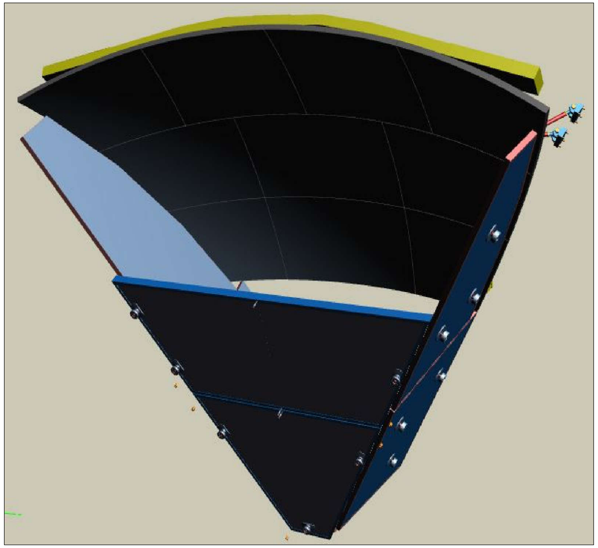
photon detector
aerogel

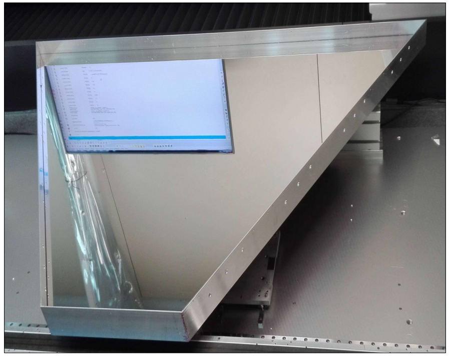


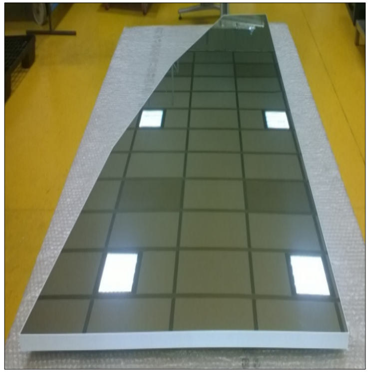
RICH Mirrors

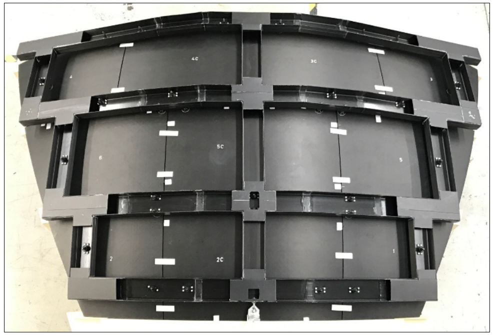
REQUIREMENTS:

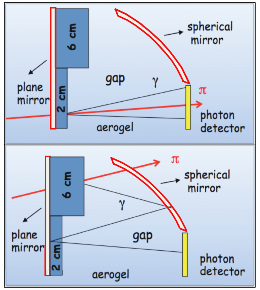
- Bring the **Cherenkov Photons toward** the **Photon Detector**
- Have <u>Angular Precision</u> **<1 *mrad***
- Have **High Reflectivity**
- Be **Light**











RICH Mirrors

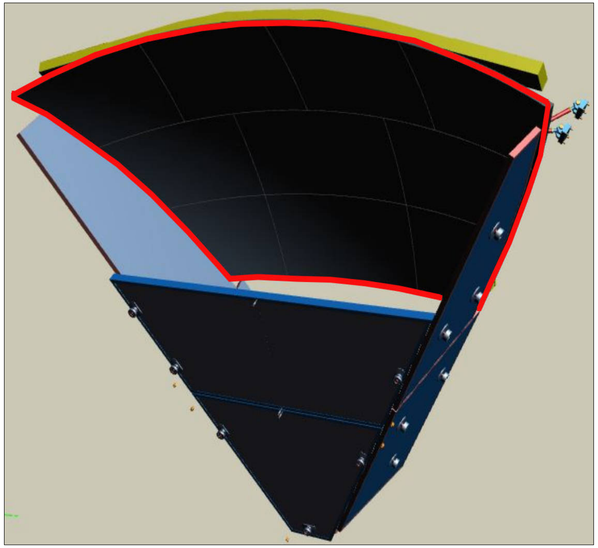
REQUIREMENTS:

- Bring the **Cherenkov Photons toward** the **Photon Detector**
- Have Angular Precision **<1 *mrad***
- Have **High Reflectivity**
- Be **Light**

10 SPHERICAL MIRRORS

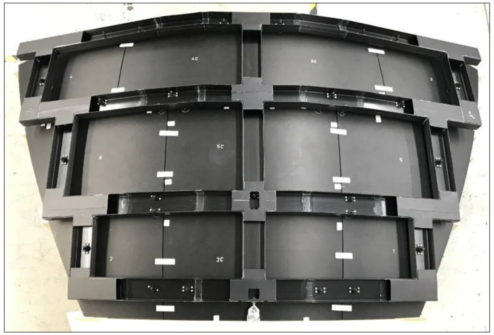
Total Surface ~3.6 m^2

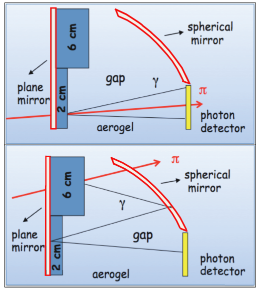
ALL PRODUCED
Coating ongoing



Carbon Fiber
sandwich of
two thin layers with
honeycomb core

as LHCb case but with
30% less of surface density





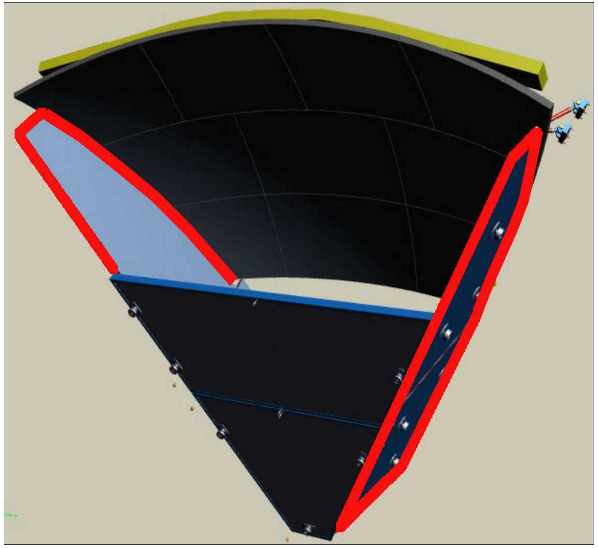
RICH Mirrors

REQUIREMENTS:

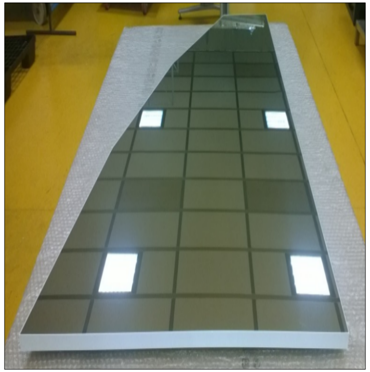
- Bring the **Cherenkov Photons toward** the **Photon Detector**
- Have Angular Precision **<1 *mrad***
- Have **High Reflectivity**
- Be **Light**

4 LATERAL
1 BOTTOM
PLANAR MIRRORS

Total Surface ~3.7 m^2



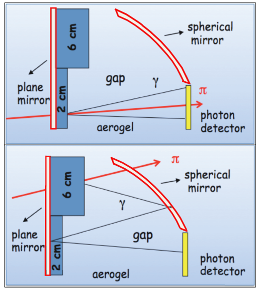
Sandwich of two thin layers of **Glass** with **Al** honeycomb core



technology used in ***telescopes***

1.7 *mm* thick

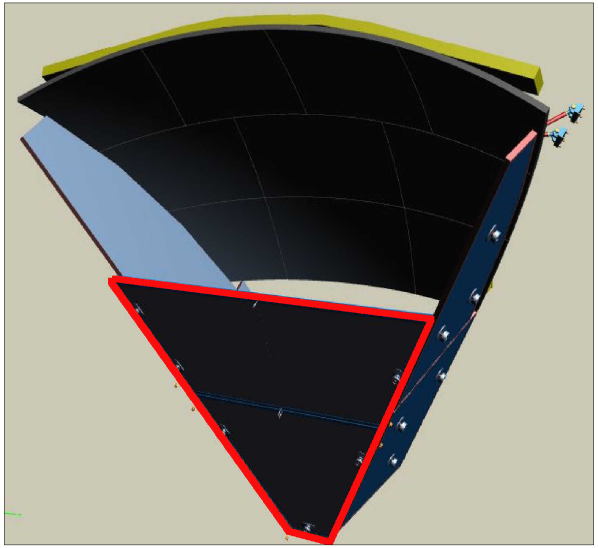
STANDARD



Mirrors

REQUIREMENTS:

- Bring the **Cherenkov Photons toward** the **Photon Detector**
- Have <u>Angular Precision</u> **<1 *mrad***
- Have **High Reflectivity**
- Be **Light**

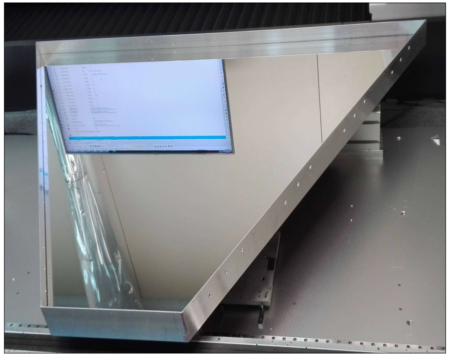


4 FRONTAL PLANAR MIRRORS

Total Surface ~3 m^2

Sandwich of <u>two</u> thin <u>layers</u> of **Glass** with **Al** <u>honeycomb core</u>

Hold the Aerogel Tiles



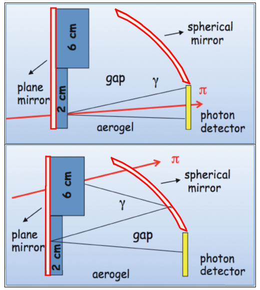
*technology used in **telescopes***

0.7 *mm* thick

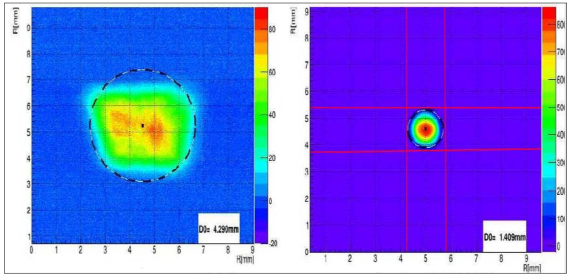
<u>DEVELOPED FOR CLAS12</u>

Radiation length comparable with carbon fiber (~1%X_0)

Mirrors

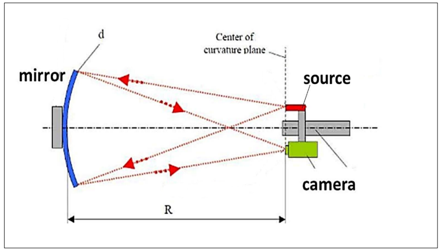


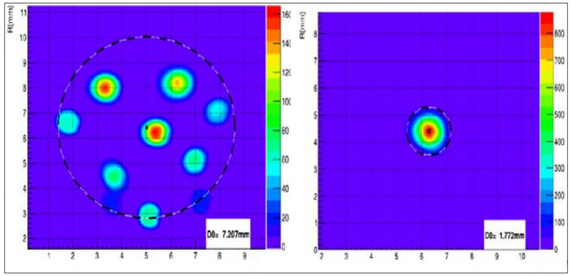
POINT LIKE IMAGE measurements



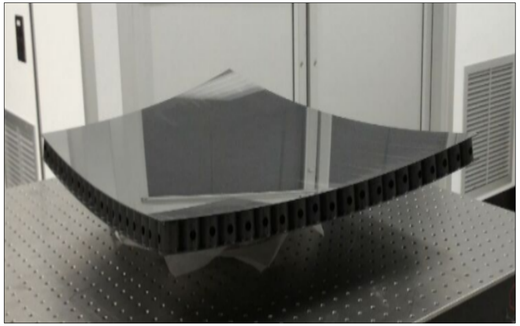
Single Mirror Quality

Optical Fiber RED LED *1 mm²*
Ximea Camera CMOSIS *1 cm²*

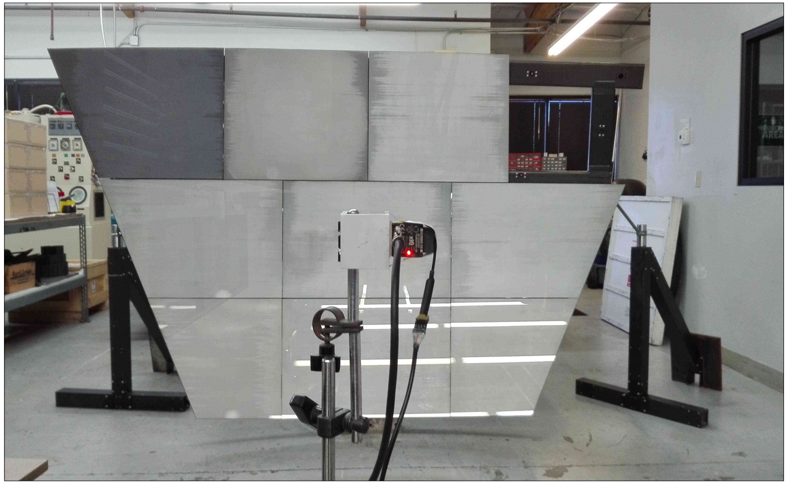


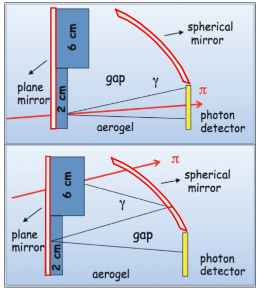


10 Mirror Alignement



REQUEST
D0 << 5 *mm*

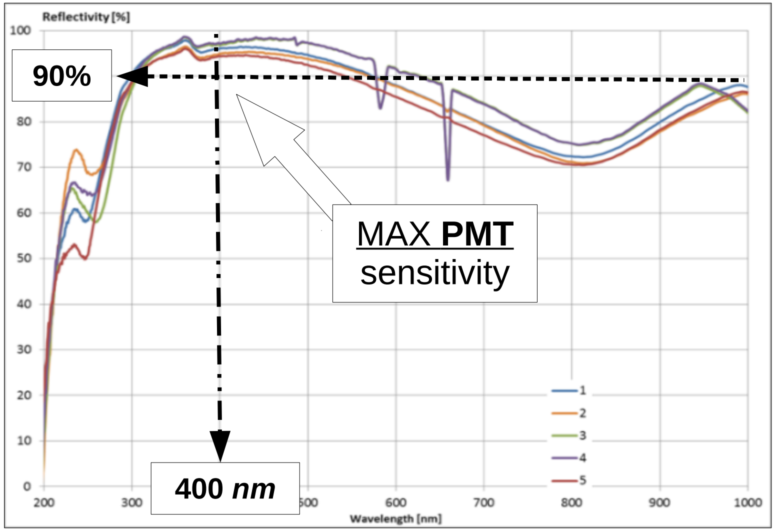




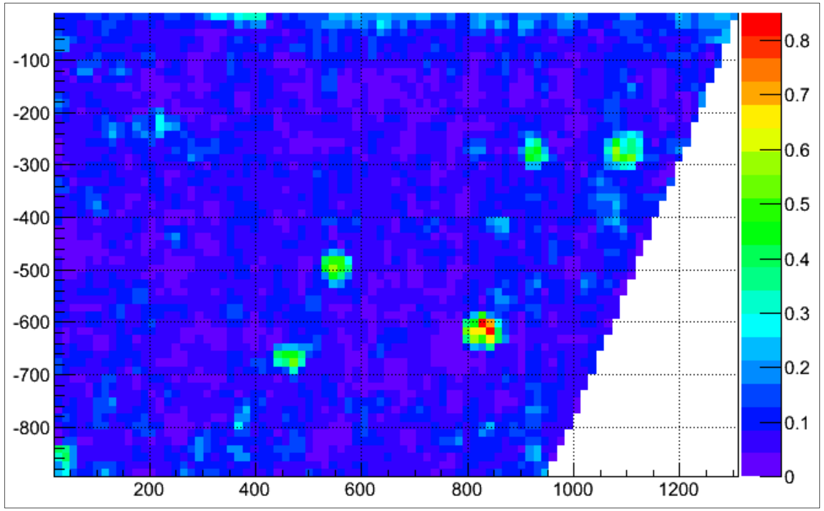
Mirrors

Surface Mapping

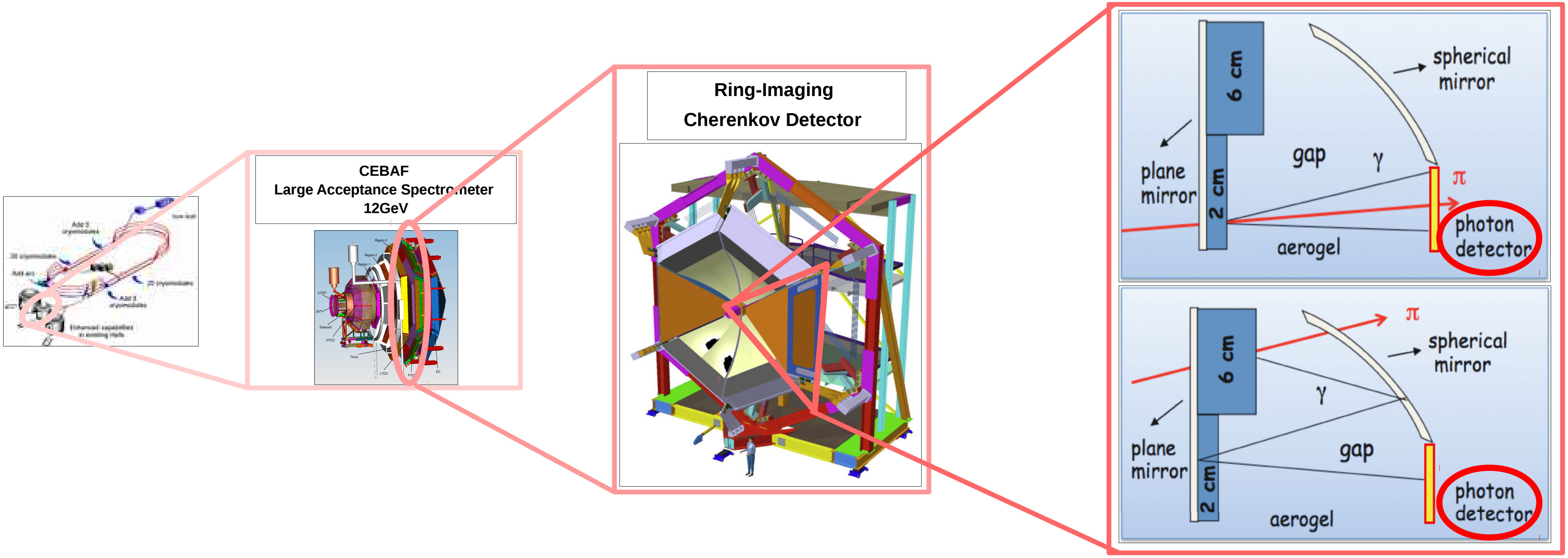
Reflectivity Tests



SURFACE SLOPE



Reflectivity > 90% at 400 *nm*


CEBAF
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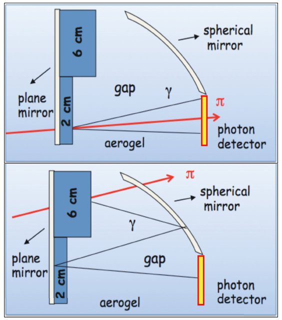


RICH Photon Detectors

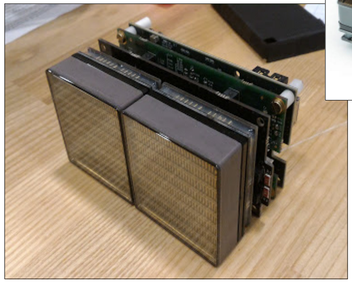
REQUIREMENTS:

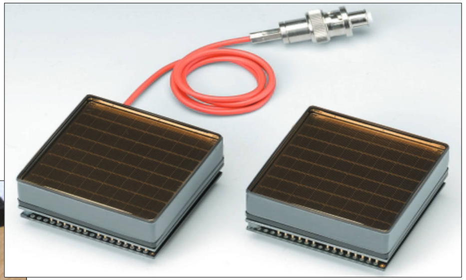
- Detect **Single Photon** Level Signals
- Be Sensitive in **Visible Light Wavelengths**
- Time Resolution **< 1 *ns***
- Spatial Resolution **< 1 *cm***
- **Minimal Deadspace** with respect to the Active Area

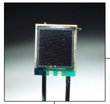
Multi-Anode PMT Hamamatsu
H8500/H12700

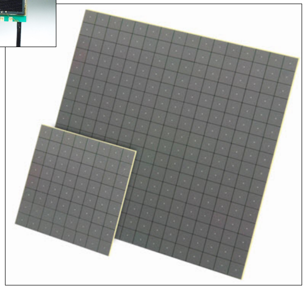
#1

- High Packing Factor (89%)
- Matrix of 64 (6x6 mm^2) pixels
- Mature and Reliable Technology
- Gain > 10^6 (~400 *fC*)
- Fast Response





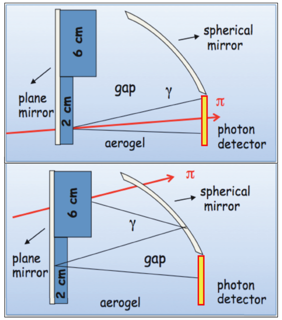




- High Gain at Low Bias Voltage
- Fast Timing
- Good Single-Photoelectrons Resolution
- Insensitivity to Magnetic Fields

#2

SiPM Hamamatsu

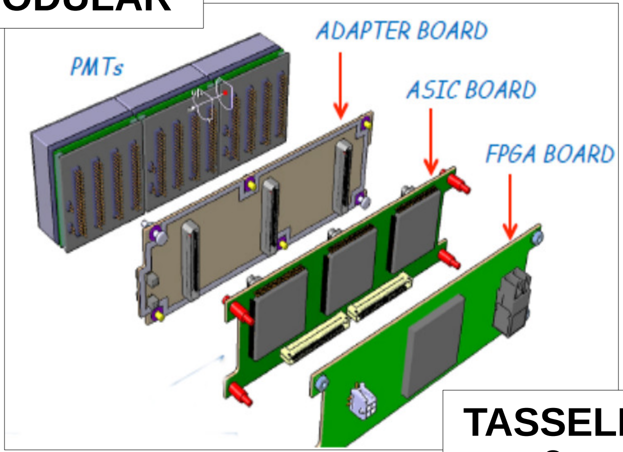


Front End Electronics

REQUIREMENTS:

- **SPE Sensitivity (minimum detectable charge 10^6 electrons)**
- <u>Time Resolution</u> **1 *ns***
- <u>Trigger Rate</u> **20 *kHz*** dead time smaller than few %
- <u>Trigger Latency</u> **8 *μs*** to be compatible with CLAS12 system
- **Gain Spread Compensation** 1:4 to compensate gain dispersion among anodes

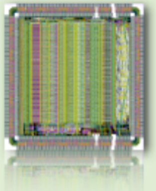
MODULAR



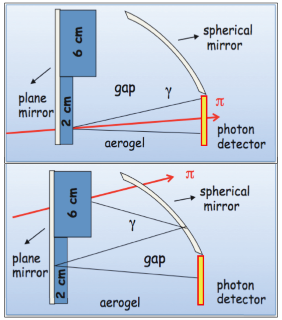
TASSELLETED
Common
HV, LV, Optical Fiber

MAROC (Multi Anode Read Out Chip)
→ <u>Single Channel</u> Adjustable **Preamplificator**
→ <u>Highly Configurable</u> **Signal Shaping**
→ **Binary Output**
→ **Charge Measurement** Available

Multi Anode- Read Out Chip
version 3
64 Channel
1.5 mW/channel
by Omega Group
Application Specific
Integrated Circuit (ASIC)

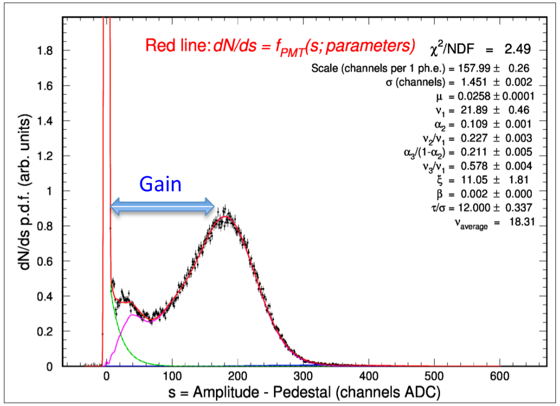


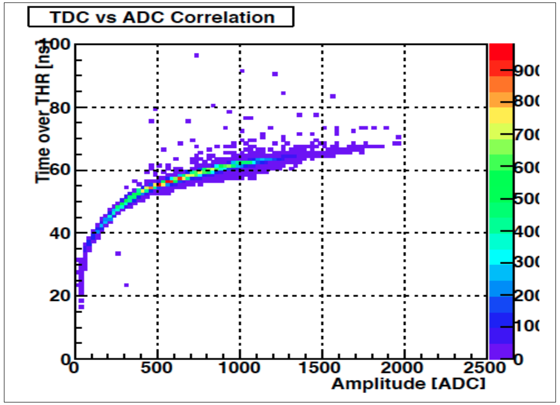
- <u>Parallel **TDC** digital readout</u>
  - ► TIME HIT → ***RICH STANDARD***
- <u>Multiplexed **ADC** charge measurements</u>
  - ► CHARGE SPECTRUM → ***CALIBRATION TOOL***

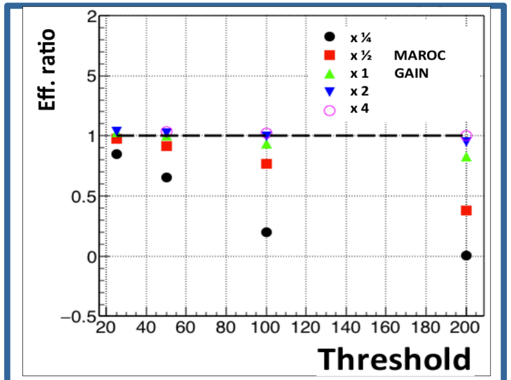


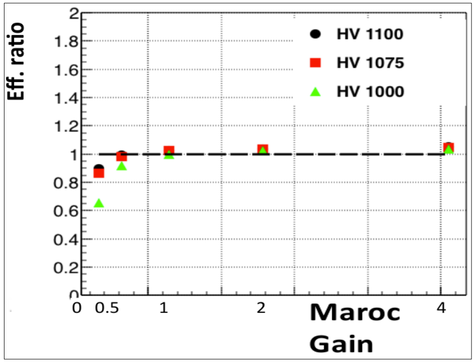
Photon Detection System

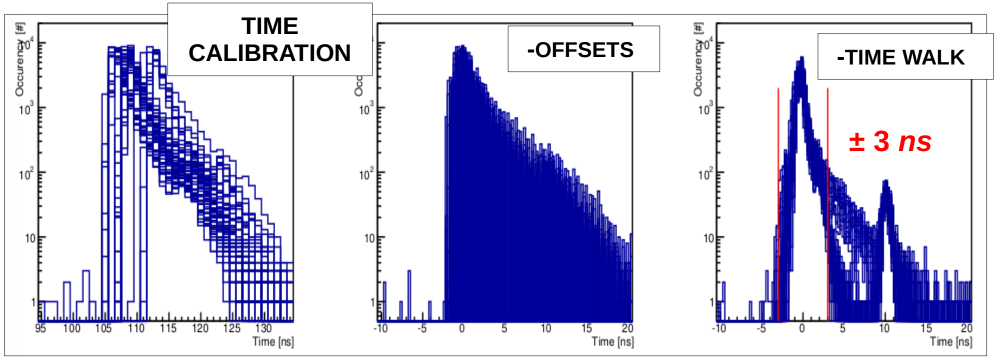
Analog:	Charge **1 *fC***
Digital:	Time **1 *ns***
Trigger latency	**8 *μs***
Optical ethernet	**2.5 *Gbps***
Trigger:	**external**
	internal
	self
On-board pulser	

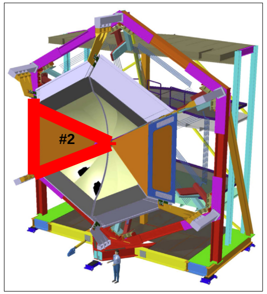








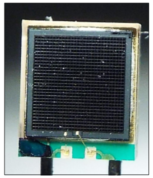


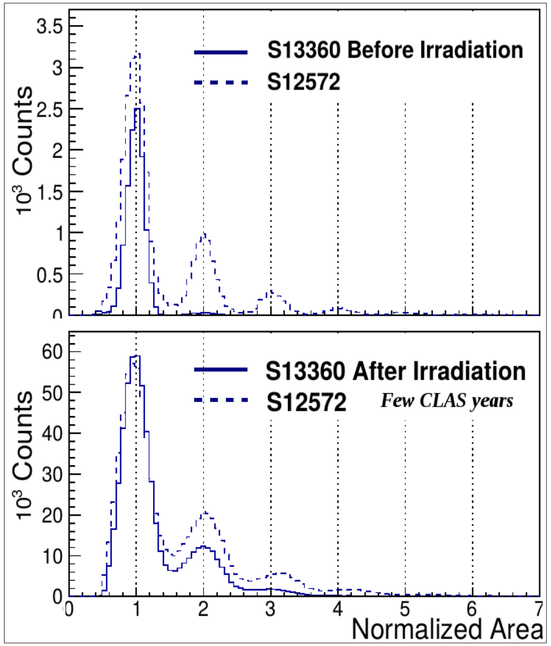


RICH **Photon Detection System**

Radiation Tolerance

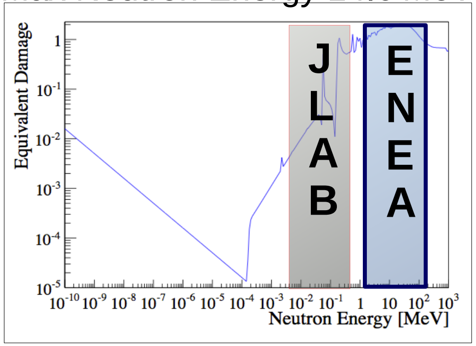
CLAS12 ENVIROMENT





d(230keV)t → n α

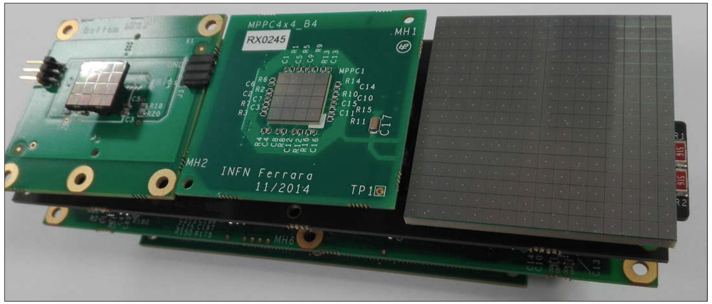
- Max flux 10^{11} s^{-1} in 4π
- Max Neutron Energy 14.6 *MeV*



S12572 Standard Technology
S13360 Trench Technology

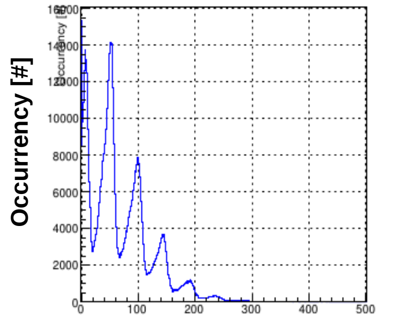
SiPM with

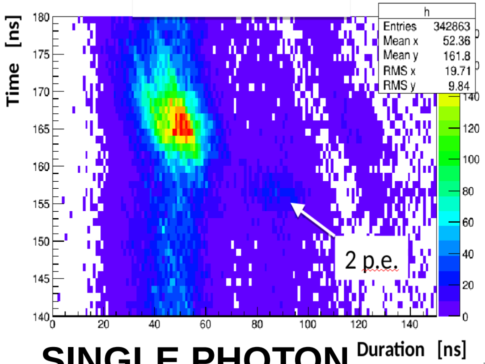
RICH Readout



PHOTON COUNTING

ADC charge measurement





SINGLE PHOTON DISCRIMINATION

TDC time measurement

Conclusions

- The **CLAS12 RICH** will provide <u>hadron identification</u>
  in the momentum range from **3 to 8 GeV/c**;

- To <u>optimize performance and material budget</u>
  a **hybrid-optic design** has been adopted;

- The <u>first</u> module (2017) will use **multi-anode PMTs**,
  for the <u>second</u> one **SiPMs matrices** are under investigation;

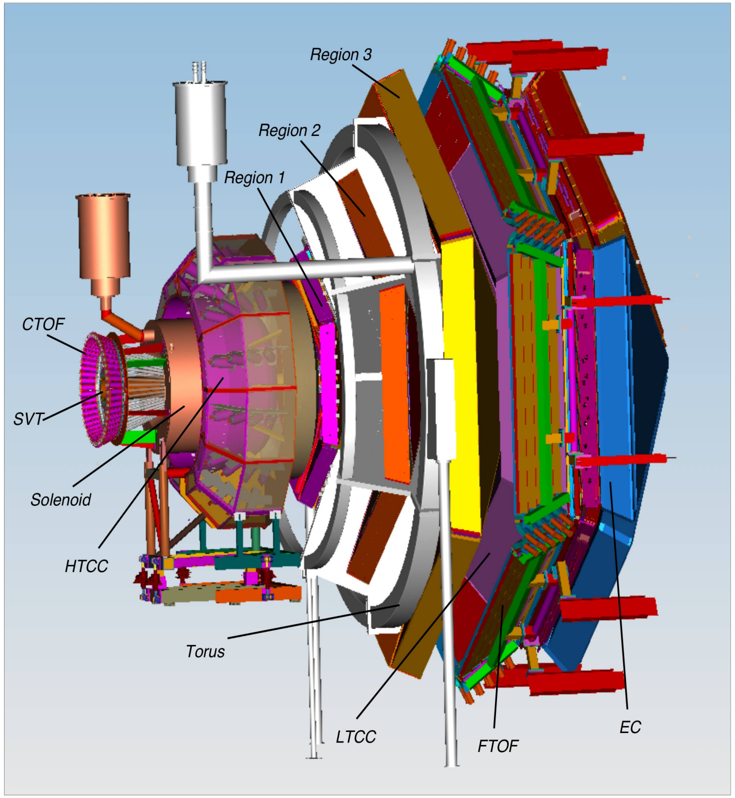
- The <u>readout electronics developed</u> is now a multi purposes one:
  will be used for GlueX DIRC and EIC R&D;

DIRC 2017 International Workshop on Fast Cherenkov Detectors

Photon detection, DIRC design and DAQ

INFN

Jefferson Lab
Thomas Jefferson National Accelerator Facility



Thanks for your attention!

RICH