

RICH PROJECT OVERVIEW

Contalbrigo Marco
INFN Ferrara

Rich Project Review, 5th September 2013

The CLAS12 Spectrometer

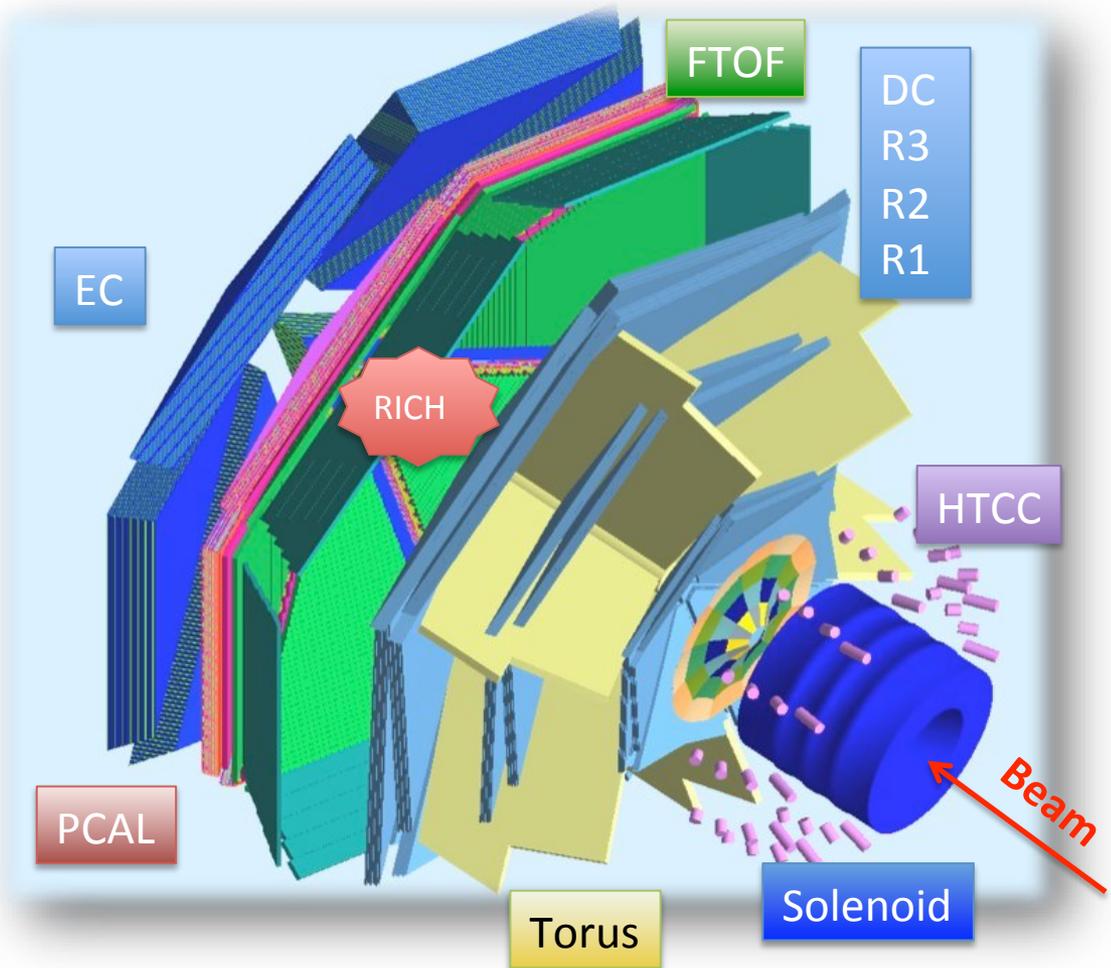
Luminosity up to $10^{35} \text{ cm}^{-2} \text{ s}^{-1}$

Highly polarized electron beam

H and D polarized targets

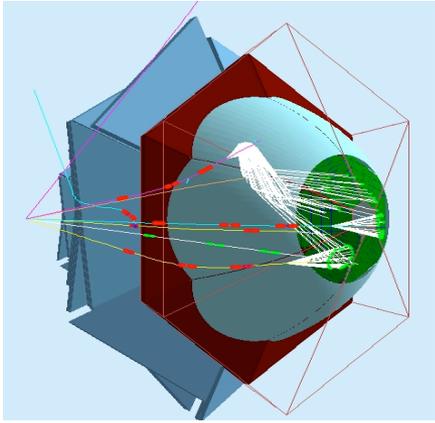
Broad kinematic range coverage
(current to target fragmentation)

RICH: Hadron ID
for flavor separation
(common to SIDIS approved exp.)



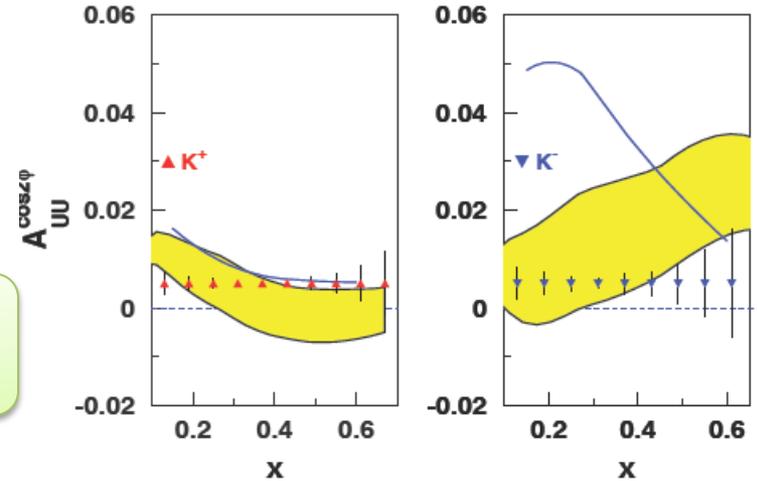
PAC30 report (2006): Measuring the kaon asymmetries is likely to be as important as pions The present capabilities of the present CLAS12 design are weak in this respect and should be strengthened.

Kaon SIDIS Program @ CLAS12



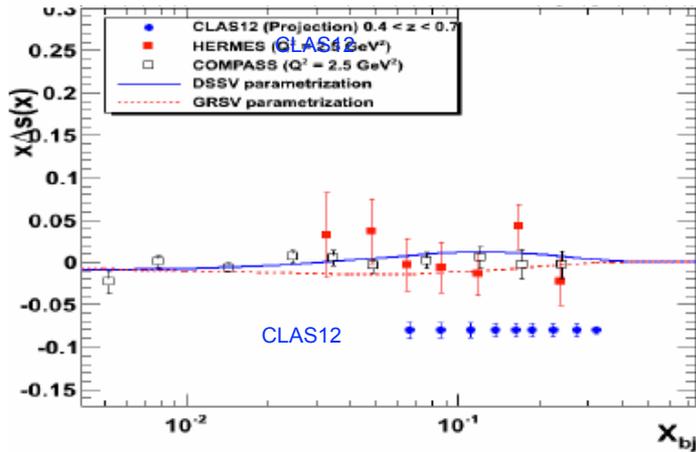
RICH detector for flavor separation of quark spin-orbit correlations in nucleon structure and quark fragmentation

E12-09-08: Studies of Boer-Mulders Asymmetry in Kaon Electroproduction with Hydrogen and Deuterium Targets



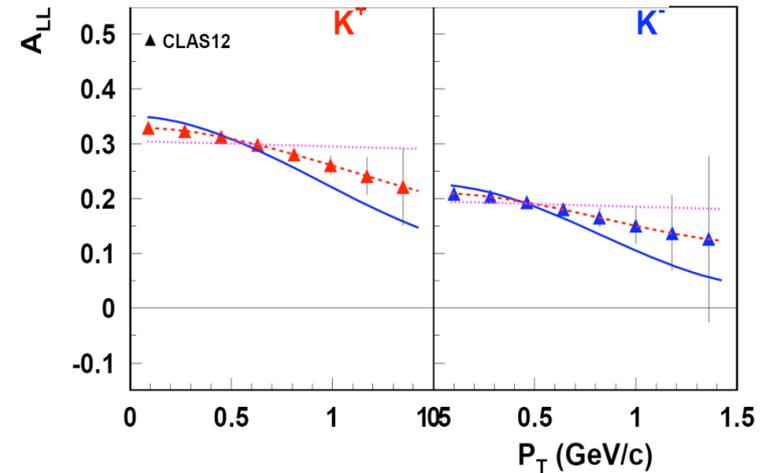
E12-09-09:

Studies of Spin-Orbit Correlations in Kaon Electroproduction in DIS with polarized hydrogen and deuterium targets



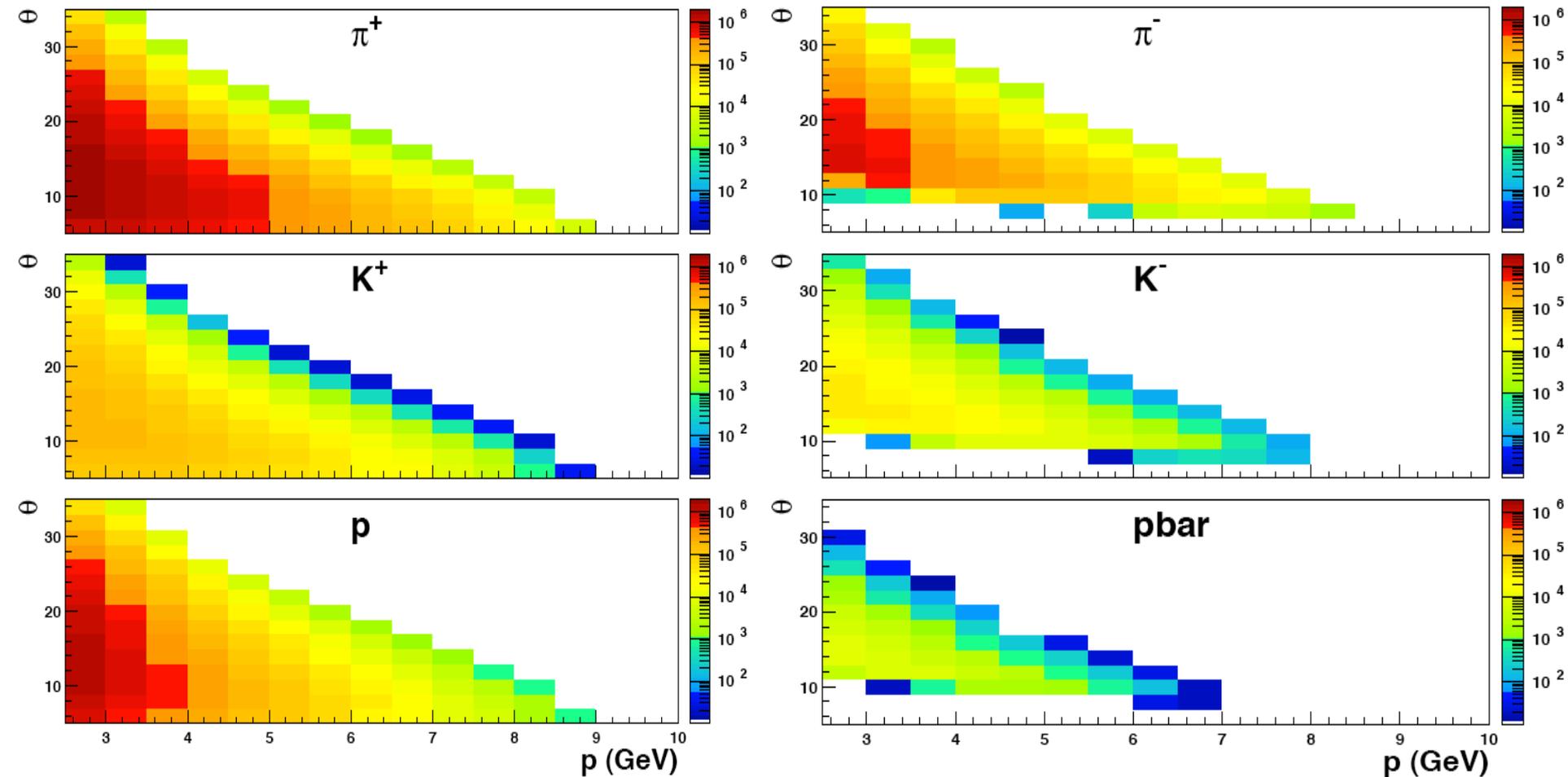
E12-09-07:

Studies of partonic distributions using semi-inclusive production of Kaons



SIDIS Kinematics @ CLAS12

A rejection factor of 1:500 is needed to suppress the background from a one-order of magnitude larger pion-proton flux to a few % level

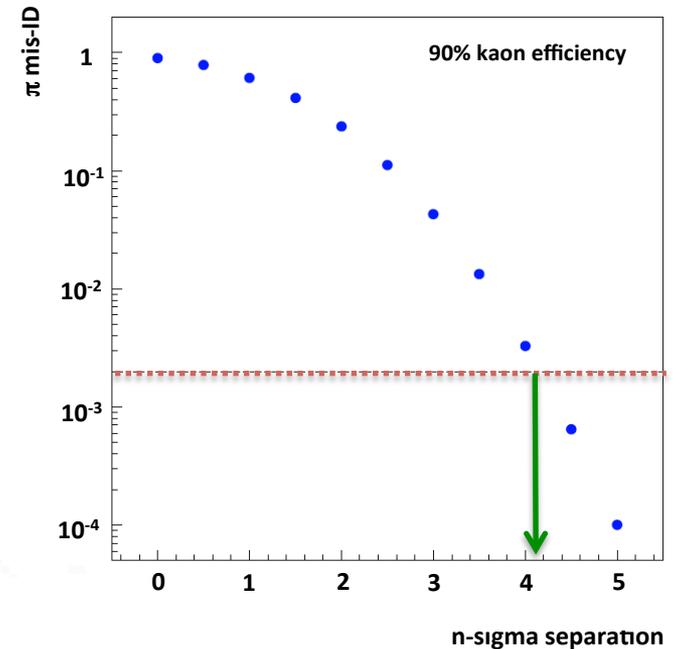
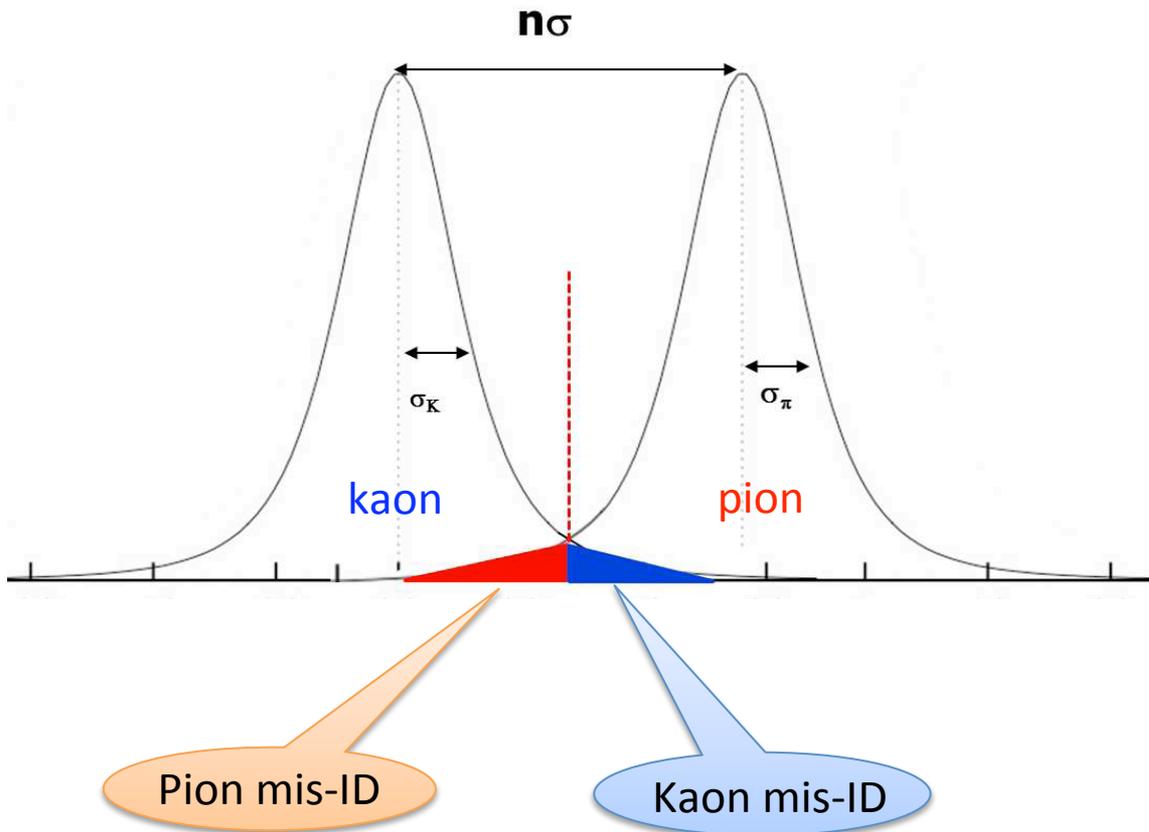


Out-bending particles

In-bending particles

SIDIS Kinematics @ CLAS12

A pion rejection factor of 1:500 for a 90% kaon efficiency corresponds to a 4σ separation in the time (TOF) or angular (Cherenkov) distributions



Baseline PID @ CLAS12

HTCC (electron ID):

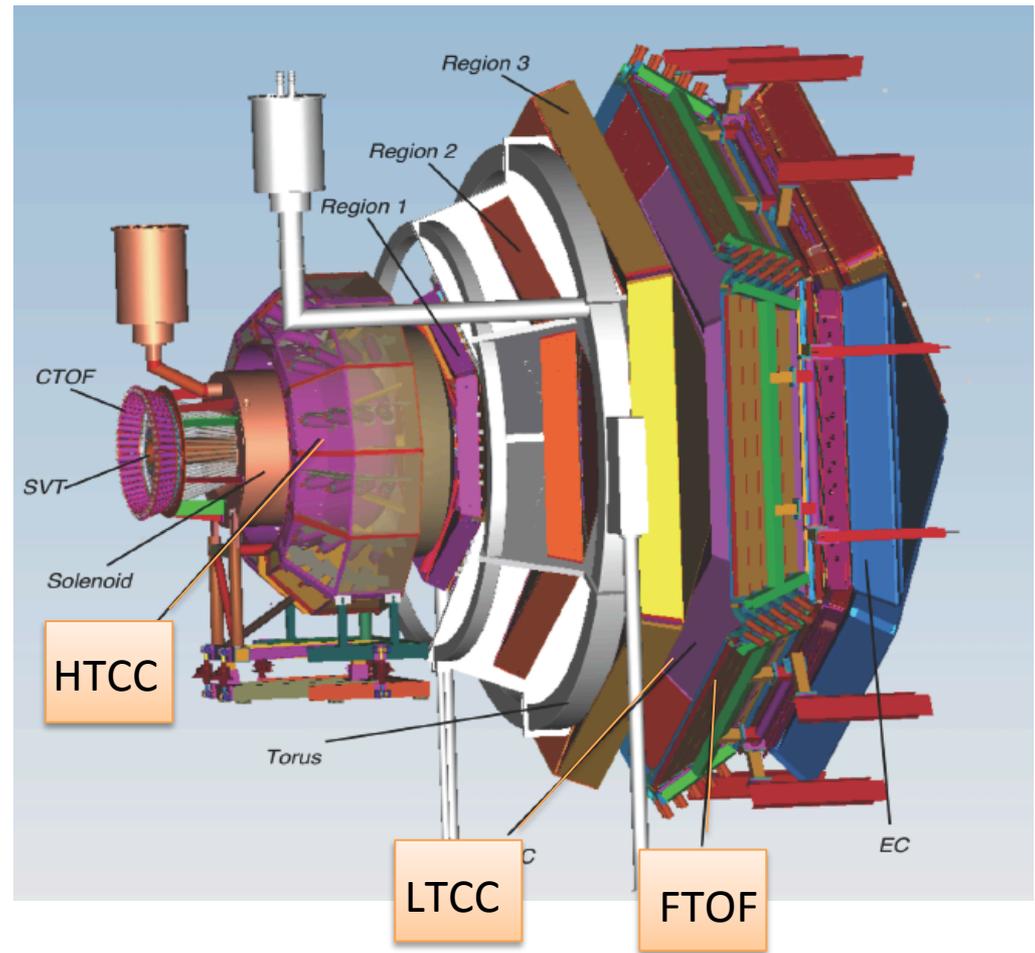
High Threshold Cherenkov Counter

FTOF (< 3 GeV/c hadron ID):

Forward Time-of-Flight system

LTCC (pion ID):

Low Threshold Cherenkov Counter



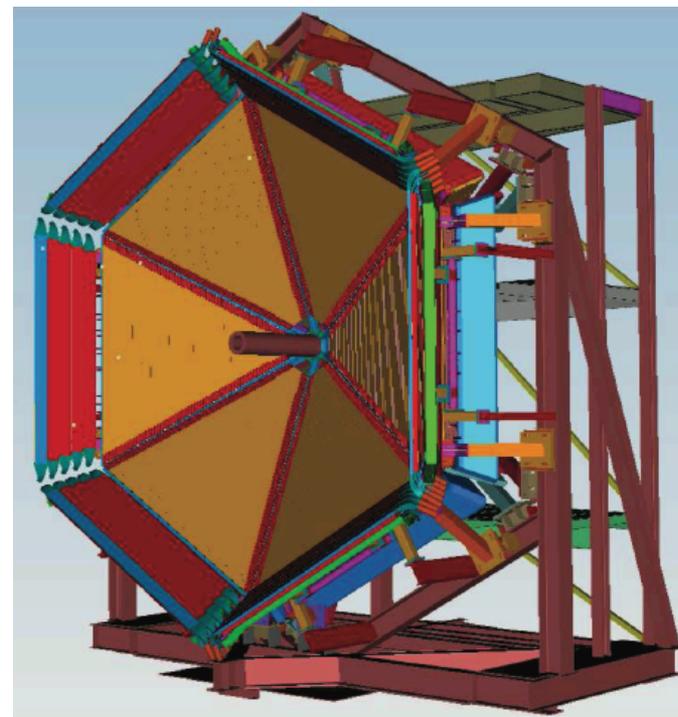
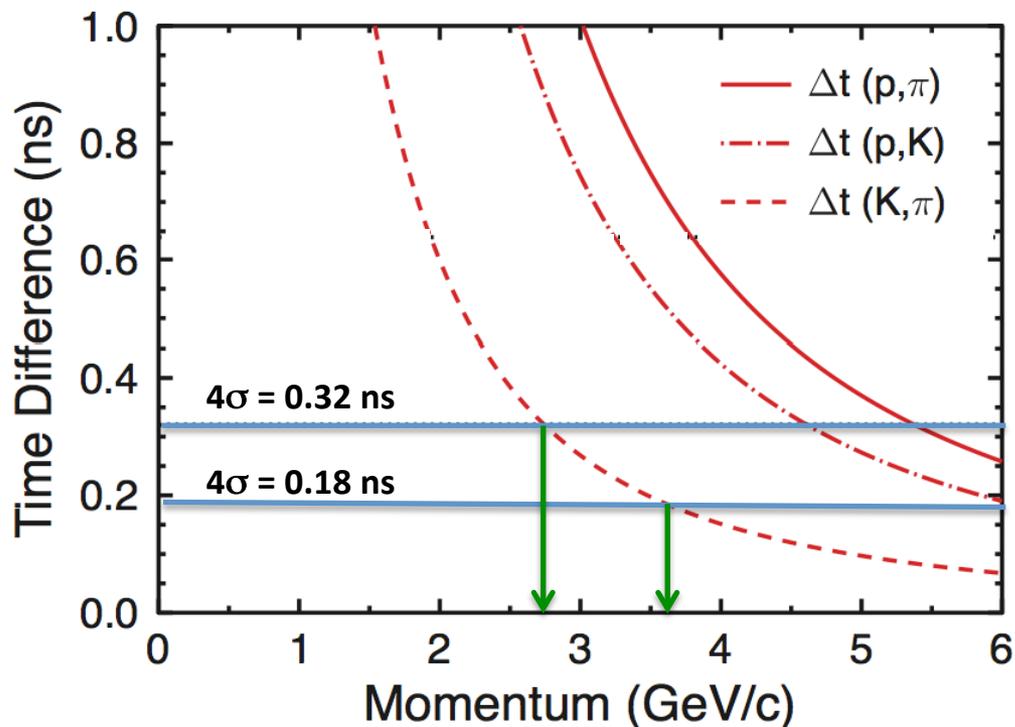
FTOF @ CLAS12

Two scintillator panels for hadron ID:
5 cm thick, 32-375 cm long slabs

Panel 1a: from CLAS, 15 cm wide

Panel 1b: new, 6 cm wide

Combined expected resolution: 45-80 ps



Suitable hadron separation achieved by time-of-flight at 650 cm from IP:

Up to 2.8 GeV/c ($\theta = 36$ degrees)

Up to 3.6 GeV/c ($\theta = 5$ degrees)

HTCC @ CLAS12

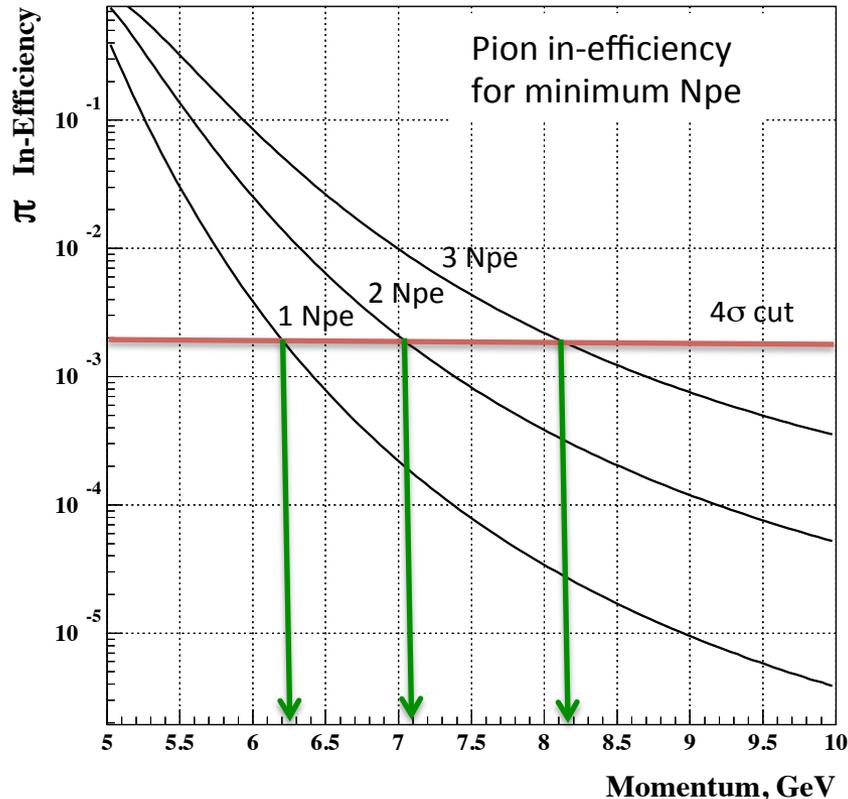
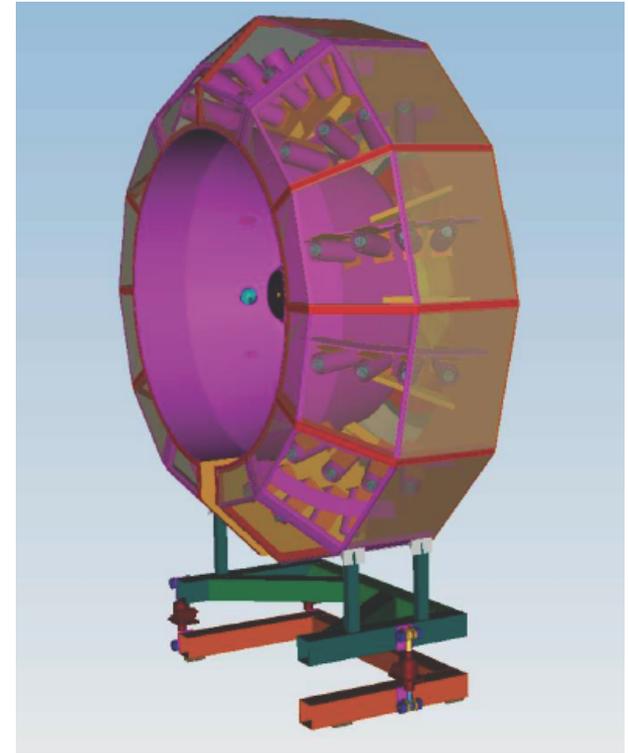
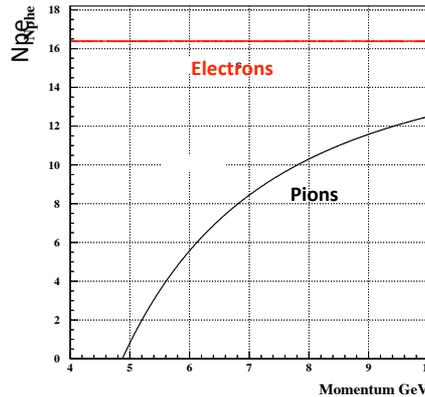
New detector for electrons ID:

CO₂ radiator

48 5" quartz window PMTs

Hermetic with uniform response

Expected p.e. number with electrons ~ 16



Pions in-efficiency for minimum 2 p.e. number:

100% below 5 GeV/c (Cherenkov threshold)

~ % level around 6 GeV/c

~ few per mil above 7 GeV/c

Requested pion separation achieved above 7 GeV/c
No kaon-proton separation

LTCC @ CLAS12

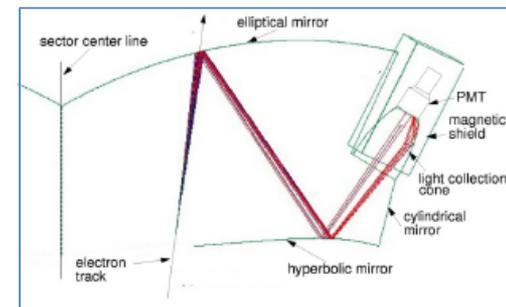
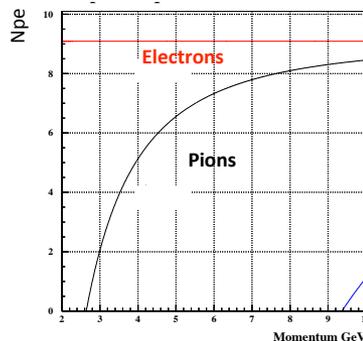
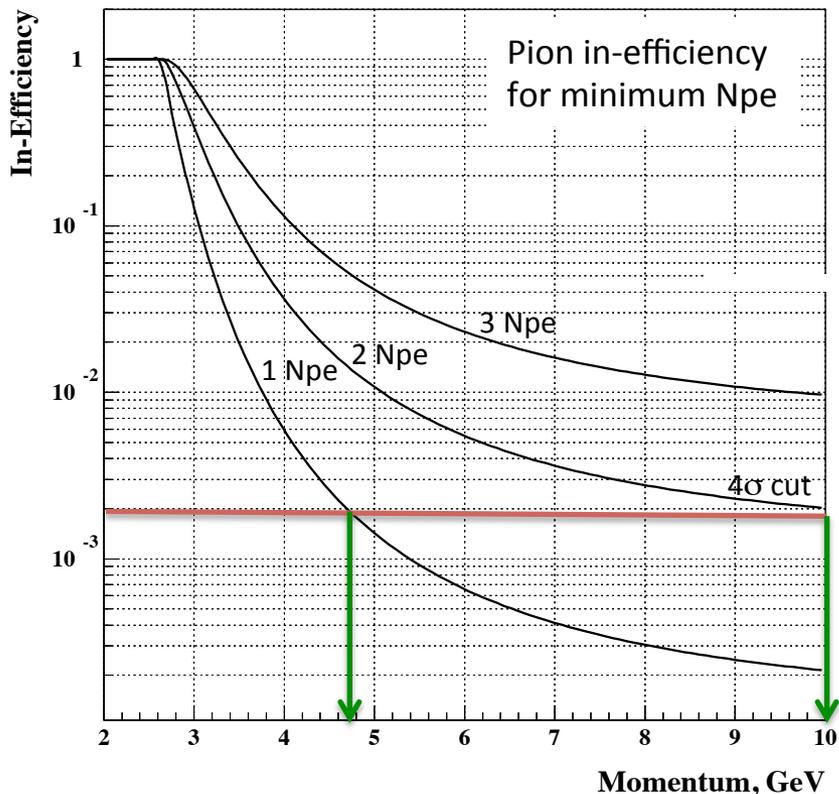
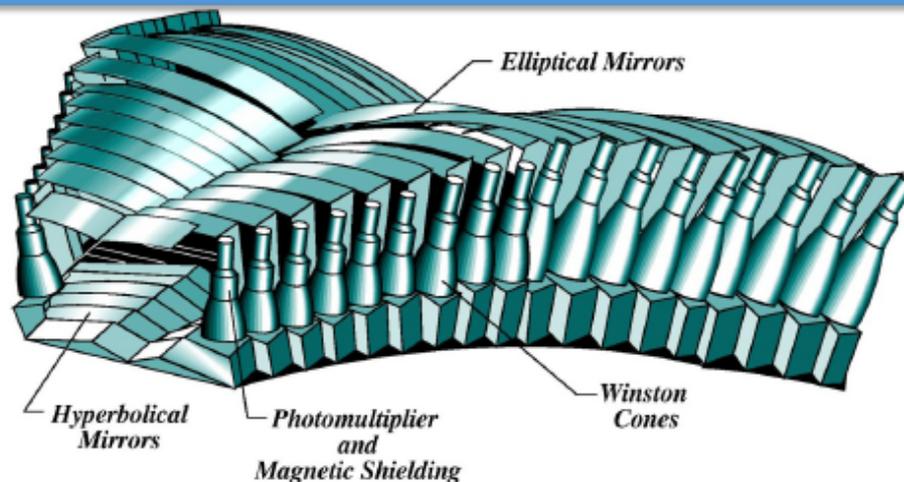
Derived from CLAS for pion ID:

C_4F_{10} radiator

Complicated design with irregular response

Limited ϕ acceptance

Expected p.e. number with electrons ~ 9



Pions in-efficiency for minimum 2 p.e. number:

100 % below 2.7 GeV/c (Cherenkov threshold)

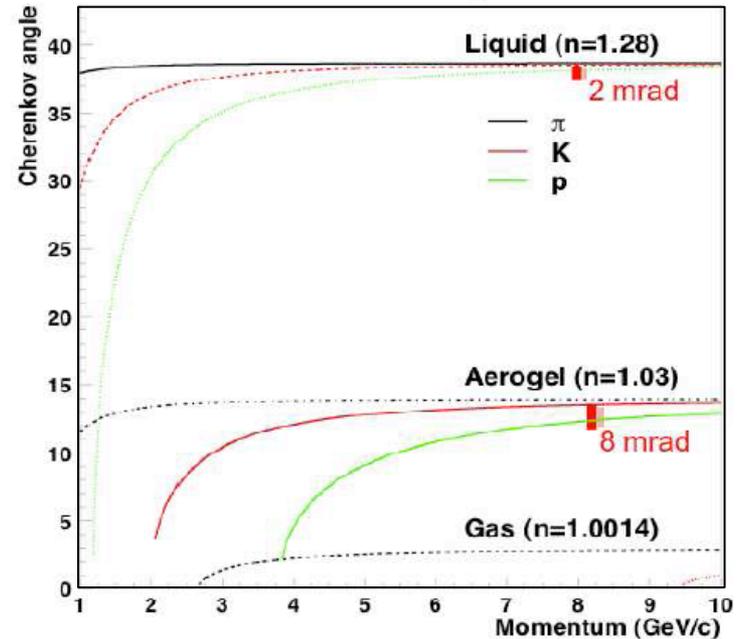
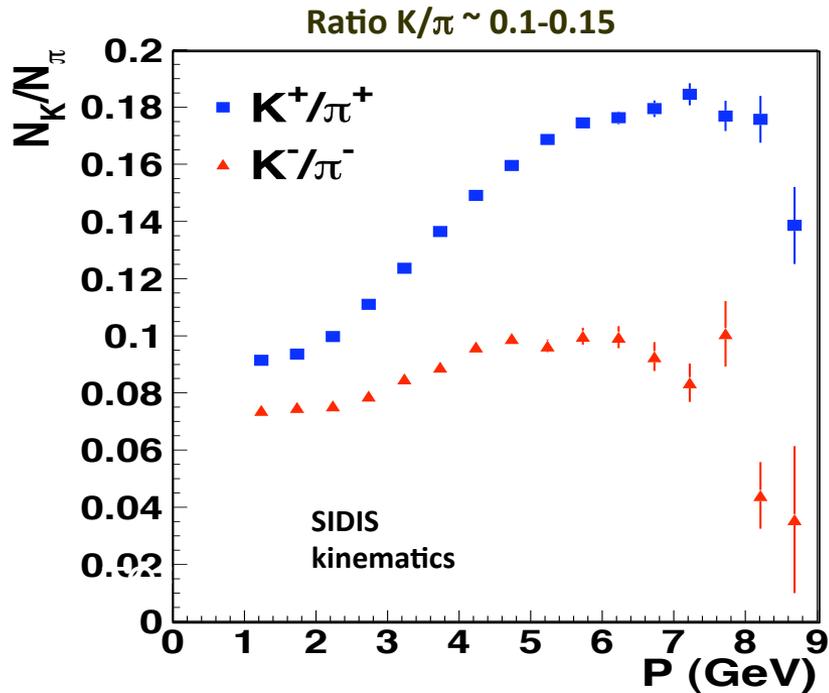
\sim % level around 5 GeV/c

\sim per mil level above 7 GeV/c

Requested pion separation achieved above 8 GeV/c
No kaon-proton separation

CLAS12 Momentum Range

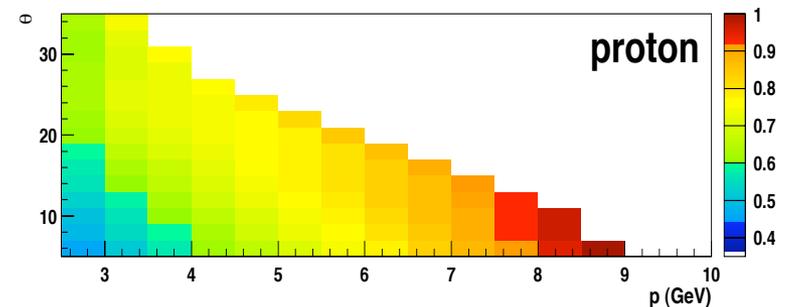
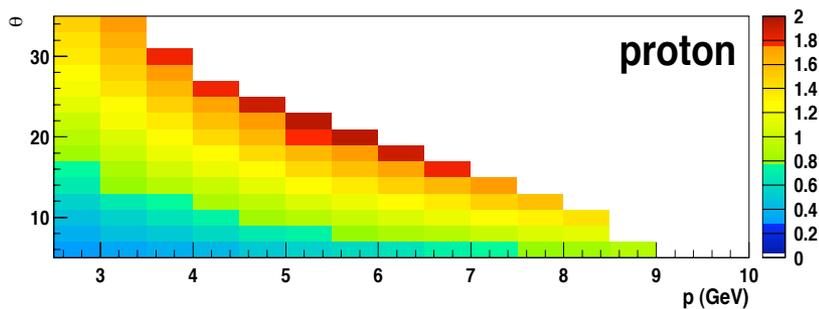
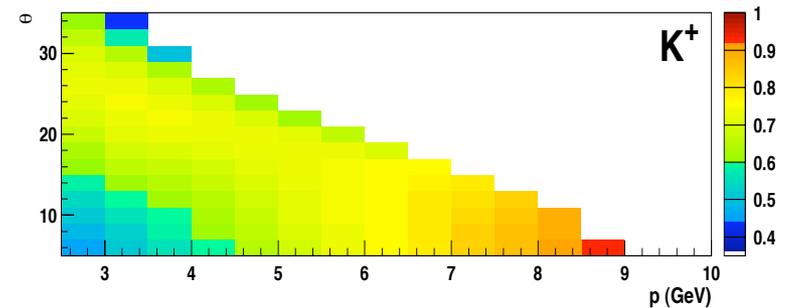
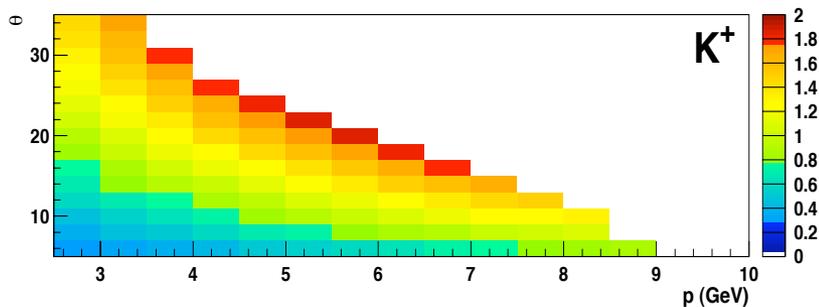
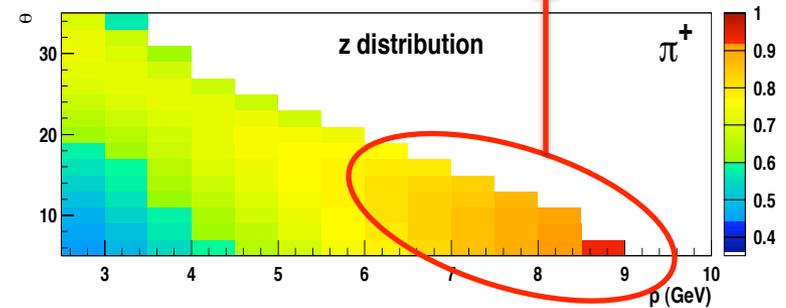
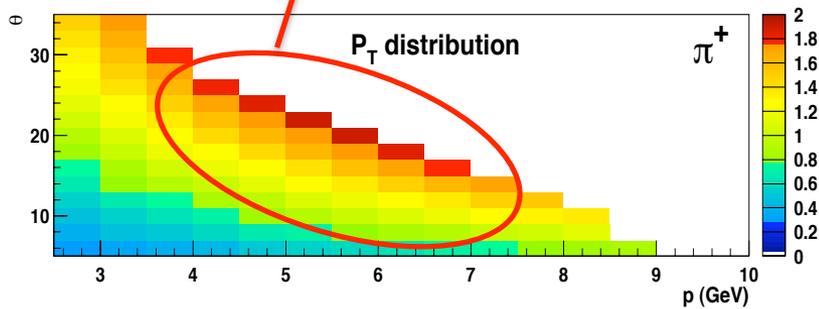
- ◆ **Aerogel** mandatory to separate hadrons in the 3-8 GeV/c momentum range with the required large rejection factors
 - collection of **visible Cherenkov light**
 - use of **PMTs**
- ◆ **Challenging project**, need to minimize detector area covered with expensive photodetectors



SIDIS Kinematics @ CLAS12

Intermediate angular range (15-25°) important to reach high P_T values

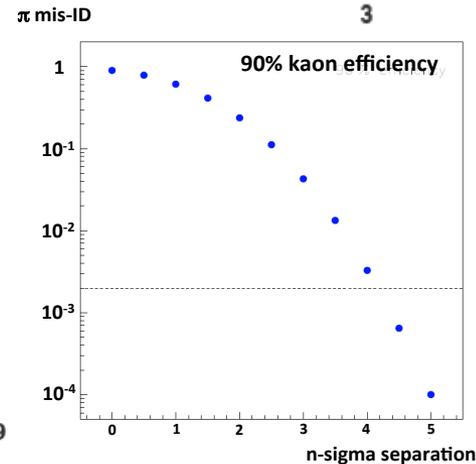
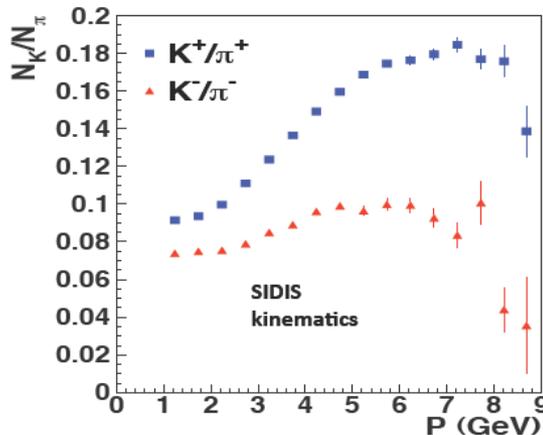
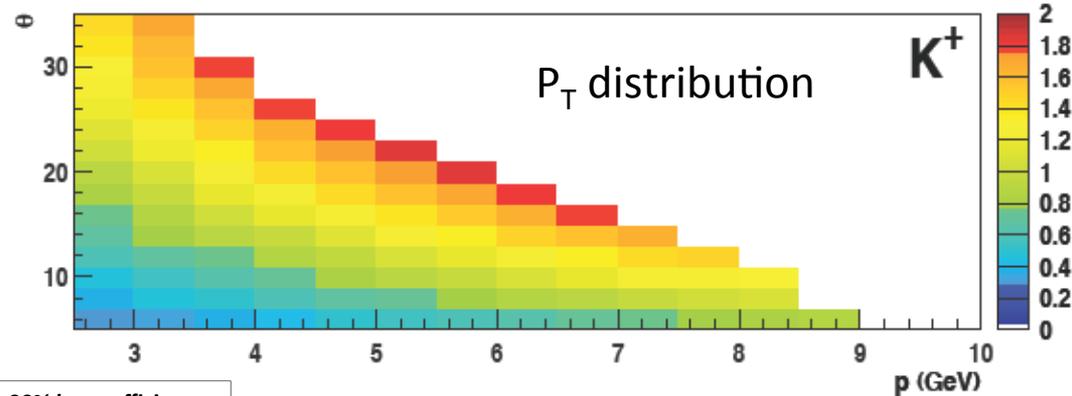
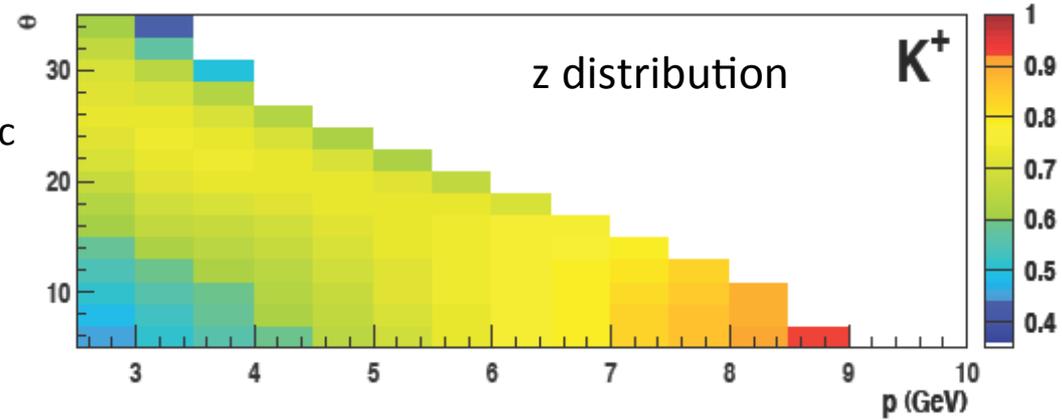
High Momentum region important as transient to hard semi-exclusive region



RICH Requirements

Full momentum coverage from 3 up to 8 GeV/c
 Pion rejection above 3 GeV/c
 Proton rejection above 5 GeV/c

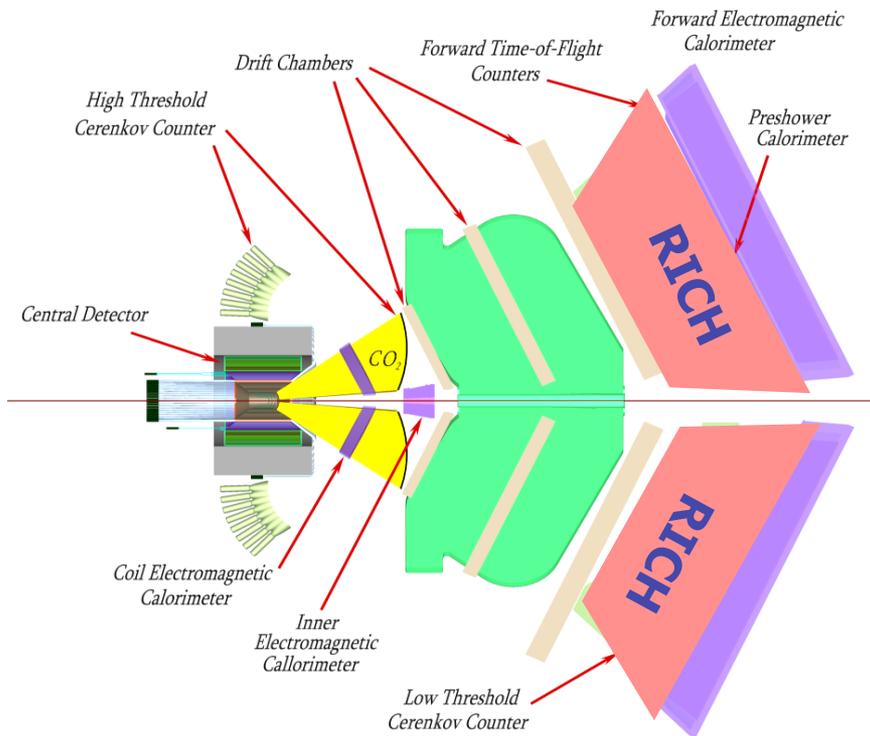
Angular coverage reaching
 above 20 and up to 25 degrees



Contamination limited at the few % level
 Pion rejection close to 500
 Proton rejection close to 100

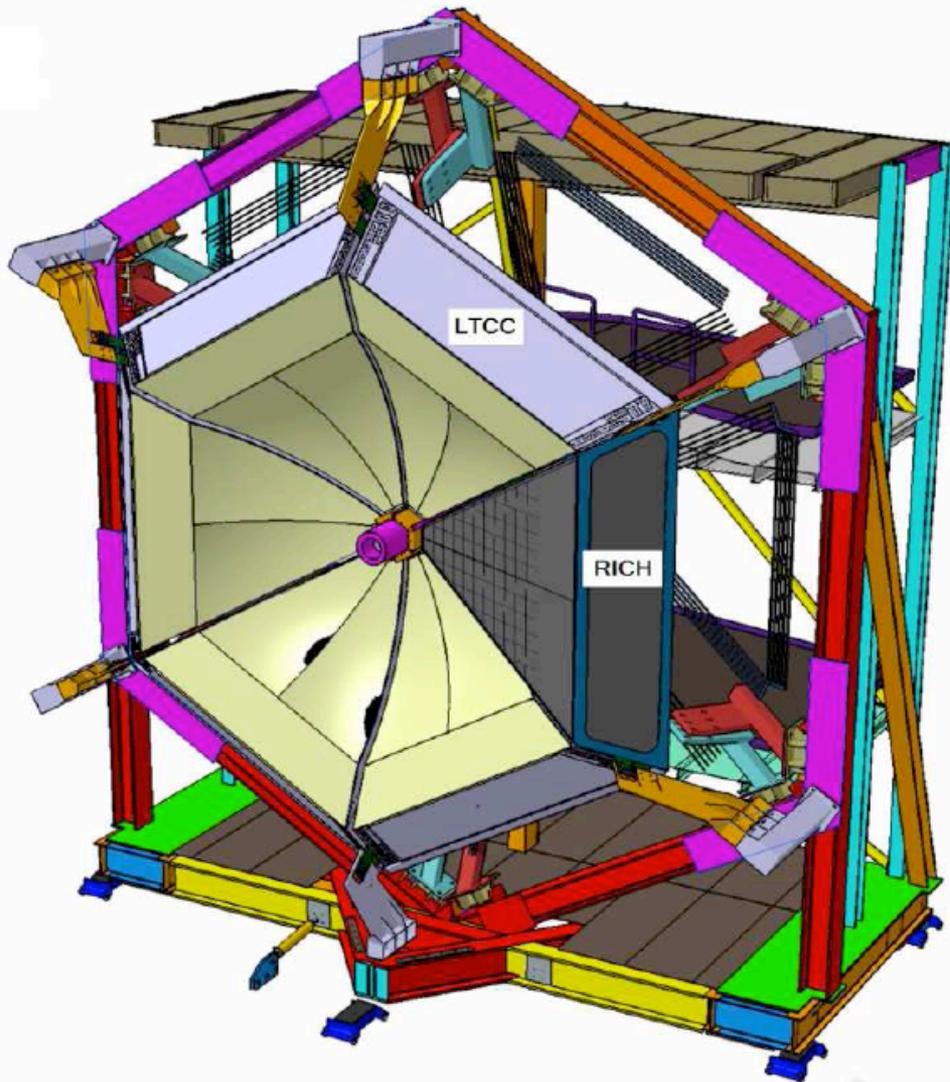
The CLAS12 RICH

RICH goal: $\pi/K/p$ identification from 3 up to 8 GeV/c and 25 degrees
 $\sim 4\sigma$ pion-kaon separation for a pion rejection factor $\sim 1:500$



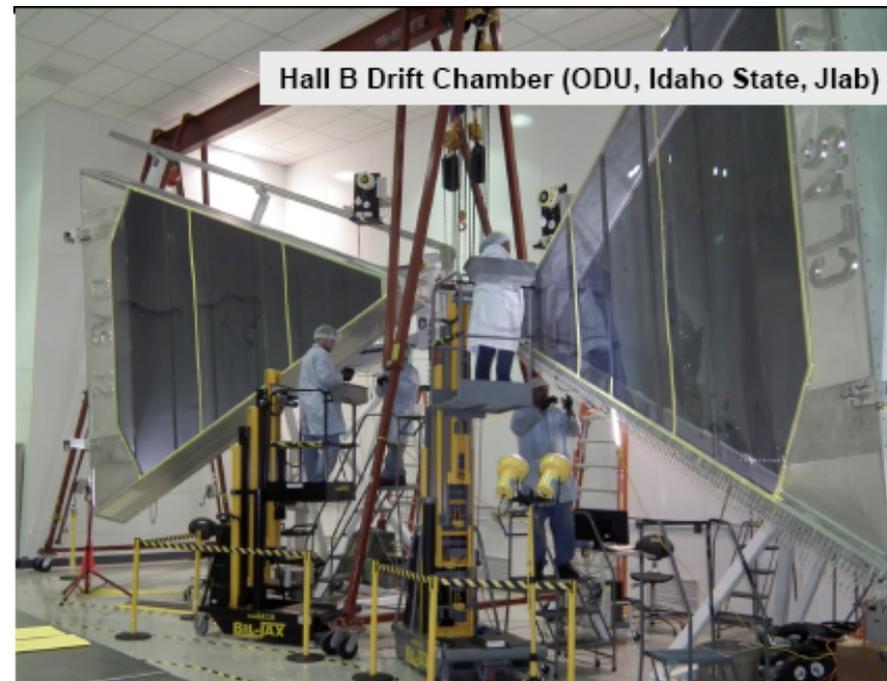
INSTITUTIONS
INFN (Italy) Bari, Ferrara, Genova, L.Frascati, Roma/ISS
Jefferson Lab (Newport News, USA)
Argonne National Lab (Argonne, USA)
Duquesne University (Pittsburgh, USA)
Glasgow University (Glasgow, UK)
J. Gutenberg Universitat Mainz (Mainz, Germany)
Kyungpook National University, (Daegu, Korea)
University of Connecticut (Storrs, USA)
UTFSM (Valparaiso, Chile)

RICH Base Configuration



1st sector by the end of 2016: one year before unpolarized and longitudinal polarized target physics runs

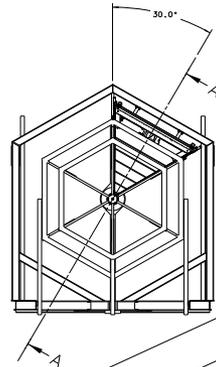
2nd++ sector useful for transverse target physics runs (left-right symmetry and statistics)



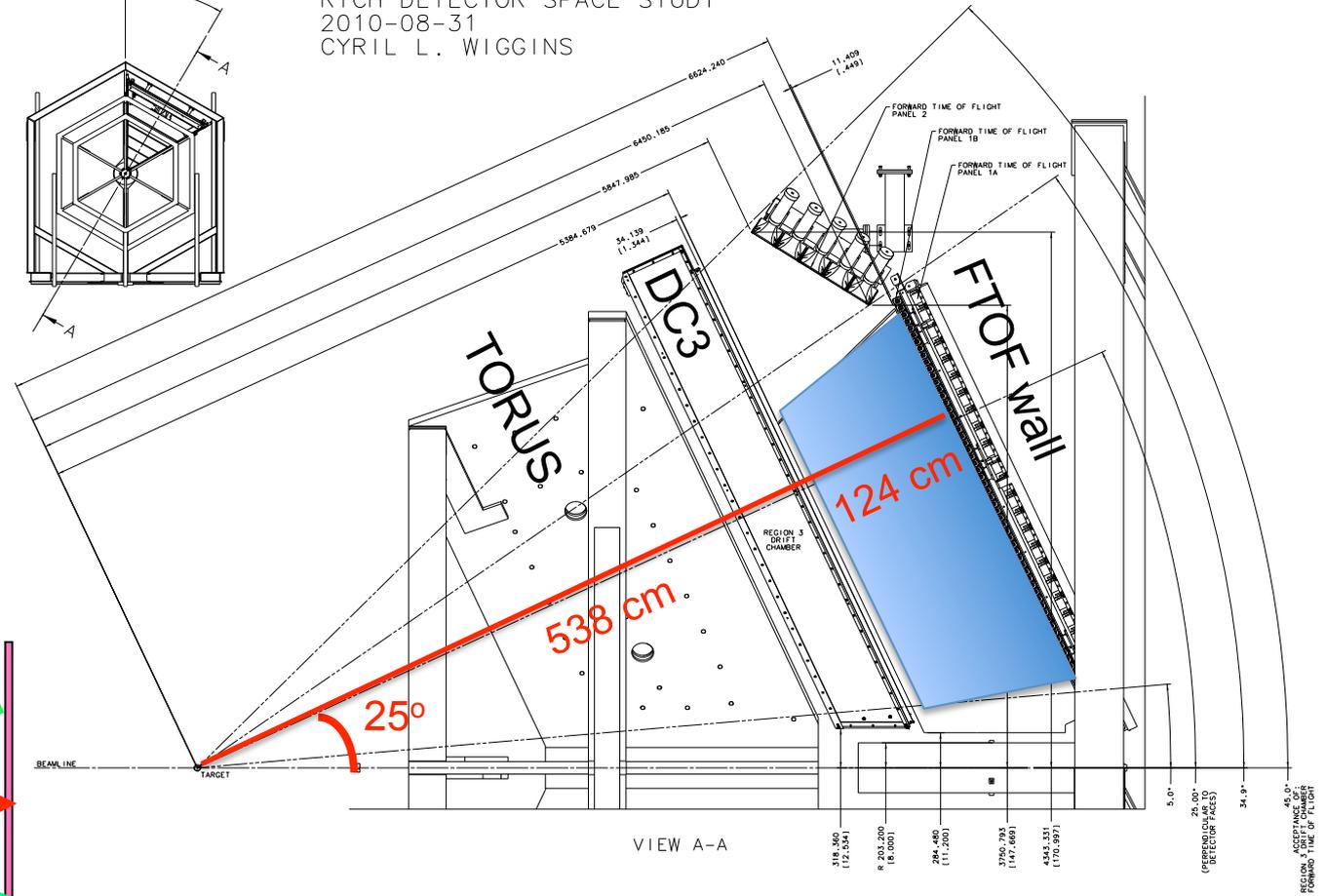
CLAS12 Geometry Constraints

Base Numbers

- ◆ 5 m from IP
- ◆ ~ 1 m gap
- ◆ Several m² surface



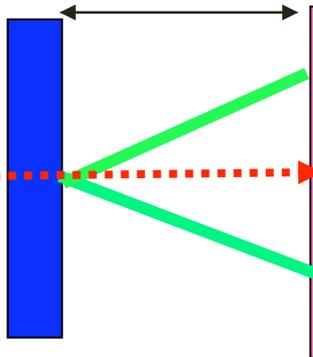
RICH DETECTOR SPACE STUDY
2010-08-31
CYRIL L. WIGGINS



Proximity RICH

Proximity gap

Charged particle



Radiator

Photon detector

RADIATOR

Aerogel Radiator



The CLAS12 large area RICH detector

M. Contalbrigo^{a,*}, E. Cisbani^b, P. Rossi^c

^a INFN Ferrara, Italy
^b INFN Roma and Istituto Superiore di Sanità, Italy
^c INFN Laboratori Nazionali di Frascati, Italy

ARTICLE INFO

Available online 28 October 2010

Keywords:
RICH
CLAS12
Particle identification

ABSTRACT

A large area RICH detector is being designed for the CLAS12 spectrometer as part of the 12 GeV upgrade program of the Jefferson Lab Experimental Hall-B. This detector is intended to provide excellent hadron identification from 3 GeV/c up to momenta exceeding 8 GeV/c and to be able to work at the very high design luminosity up to $10^{33} \text{ cm}^{-2} \text{ s}^{-1}$. Detailed feasibility studies are presented for two types of radiators, aerogel and liquid C_6F_{14} freon, in conjunction with a highly segmented light detector in the visible wavelength range. The basic parameters of the RICH are outlined and the resulting performances, as defined by preliminary simulation studies, are reported.

© 2010 Elsevier B.V. All rights reserved.

The study of the structure of nucleons and nuclei with the help of the high-resolution spectrometers of CLAS12, will allow us to investigate the structure of nucleons and nuclei in the non-perturbative regime of QCD. The main focus of the CLAS12 program is the study of the structure of nucleons and nuclei in the non-perturbative regime of QCD. The main focus of the CLAS12 program is the study of the structure of nucleons and nuclei in the non-perturbative regime of QCD.

Important observables that will be extensively investigated are transverse Momentum Distribution functions (TMDs) describing partonic spin-orbit effects and Generalized Parton Distribution functions (GPDs), containing information about the spatial distribution of quarks and the relation (by a sum rule) to the elusive parton orbital momenta. Several experiments have been already performed by the JLab12 PAC to study kaon versus pion production in exclusive and semi-inclusive scattering, providing access to the decomposition of the two sets of non-perturbative parton functions.

Main features of CLAS12 include a high operational design luminosity of $10^{33} \text{ cm}^{-2} \text{ s}^{-1}$, an order of magnitude higher than CLAS, and operation of highly polarized beam and target. The conceptual design of the CLAS12 detector is shown in Fig. 1. The central detector with the high-field (5 T) torus magnet is used for particle tracking at large angles. The CLAS12 detector detects charged and neutral particles in the angular range between 5 and 40° . It employs a 2 T torus magnet with a detector symmetry of CLAS. In the base equipment,

Detailed feasibility studies are presented for two types of radiators, aerogel and liquid C_6F_{14} freon, in conjunction with a highly segmented light detector in the visible wavelength range. The basic parameters of the RICH are outlined and the resulting performances, as defined by preliminary simulation studies, are reported.

tion and event reconstruction can be achieved in this momentum range by replacing the existing low-threshold Cherenkov counter (LTCC) with a RICH detector without any impact on the baseline design of CLAS12.

2. The CLAS12 RICH

To fit into the CLAS12 geometry, the RICH should have a projective geometry with six sectors that cover the space between the torus cryostats and covering scattering angles from 5° to 40° . Fig. 3. Being downstream to the torus magnet at the interaction point, the RICH has to cover a large area each sector spanning an area of the order of 4 m^2 . Between detectors which are already in the construction, the gap depth cannot exceed 1 m. The proposed solution is a solenoidal focusing RICH.

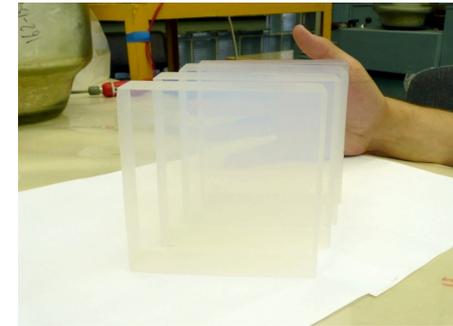
A setup similar to the one adopted in Hall-B (CLAS) is a C_5F_{12} or C_6F_{14} radiator and a CsI-deposited on a cylindrical chamber as a UV-photon detector, which is required pion rejection factor at momenta between 3 and 8 GeV/c.

The preliminary results on ongoing Monte Carlo studies, based on a GEANT3 toolkit with simplified geometry and optical surface

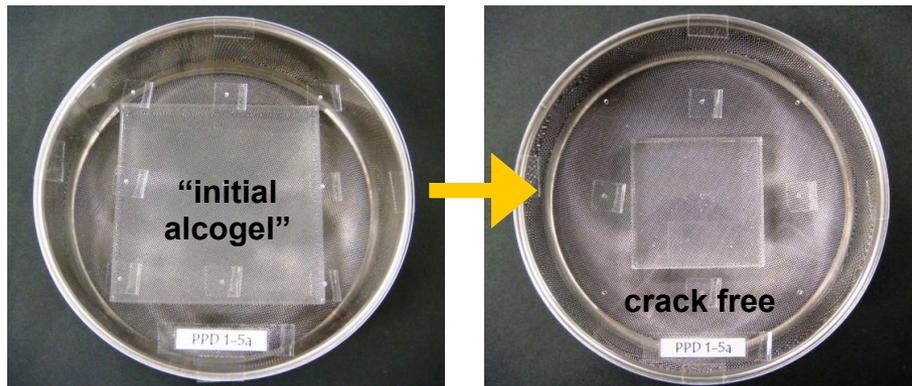
* Corresponding author.
E-mail address: mcontal@fe.infn.it

Aerogel Transmission Length

“Pinhole drying (PD)” method:
artificially shrinks alcogel to obtain high index
Transparency doubled for $n > 1.05$ aerogel



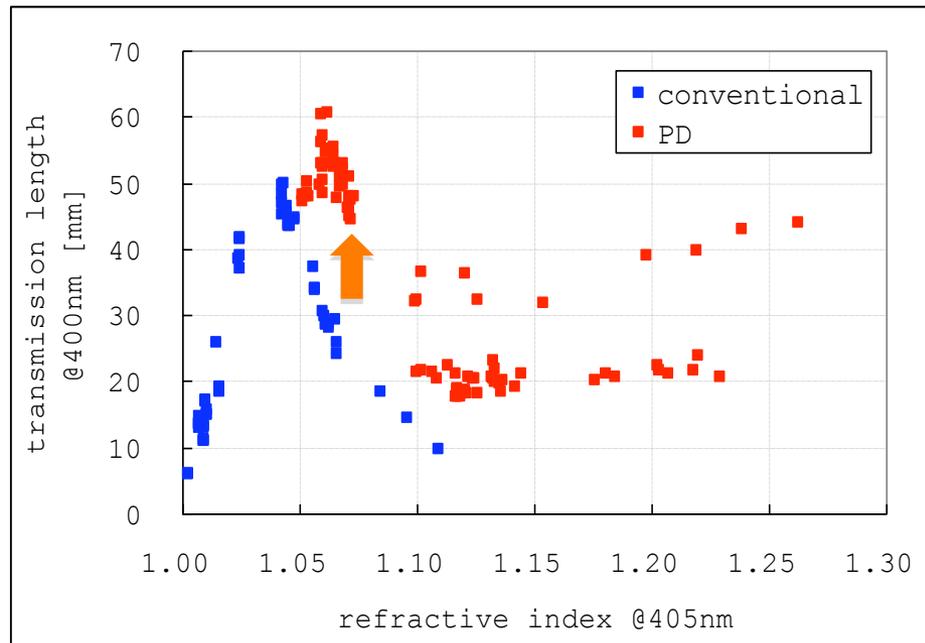
M. Tabata @ RICH 2010



pinhole drying process

A.F. Danilyuk @ RICH 2010

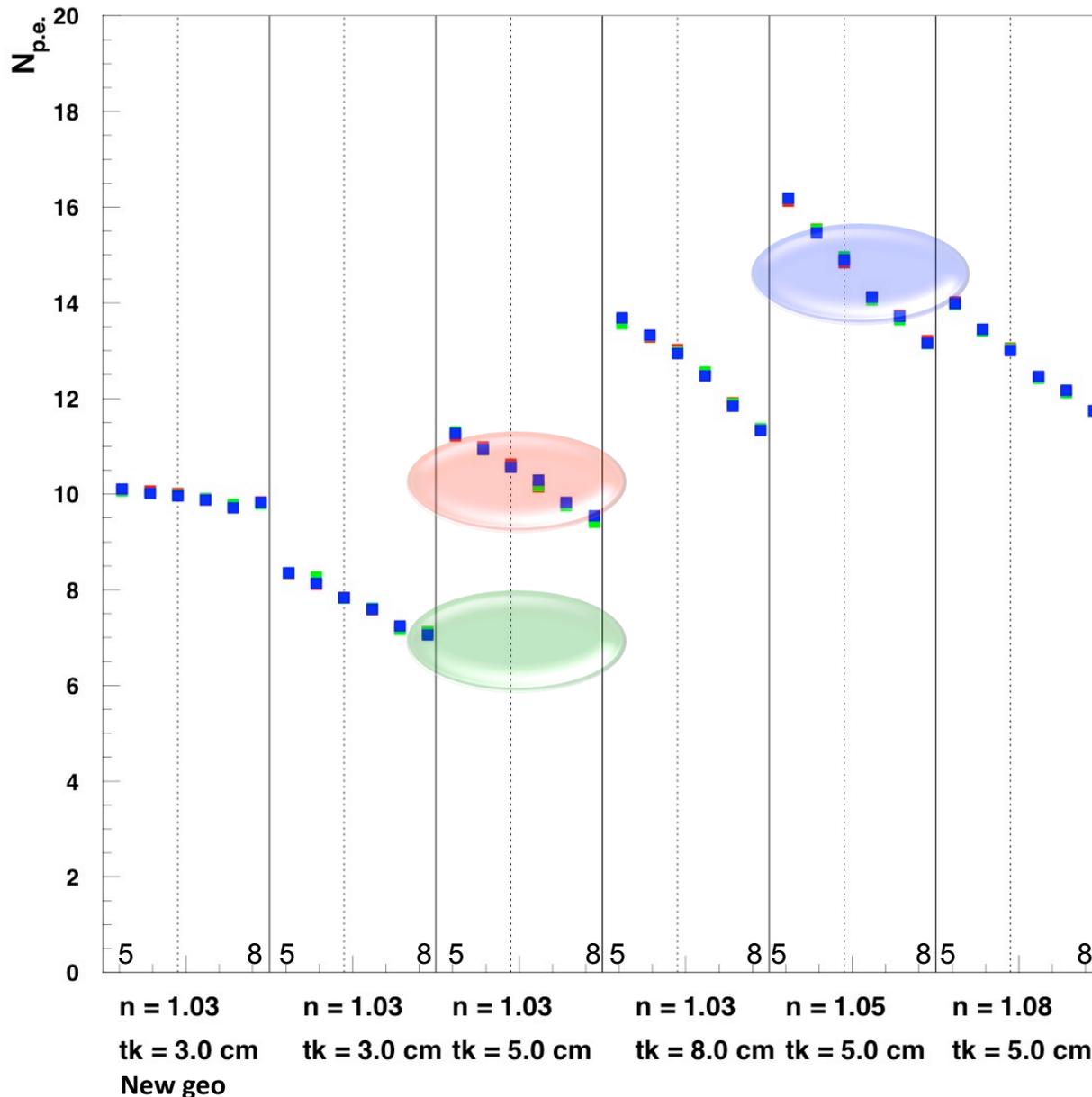
Dens., g/cm ³	n	Lsc(400), mm
0.325	1.070	41.9
0.302	1.060	56.5



$$n^2(400nm) = 1 + 0.438\rho$$

Aerogel Tests
(L. Pappalardo)

Mean p.e. Number (5-8 GeV/c)



BELLE II test-bench

15 p.e. with aerogel of $n \sim 1.05$ refractive index and 4 cm thickness

HERMES experiment

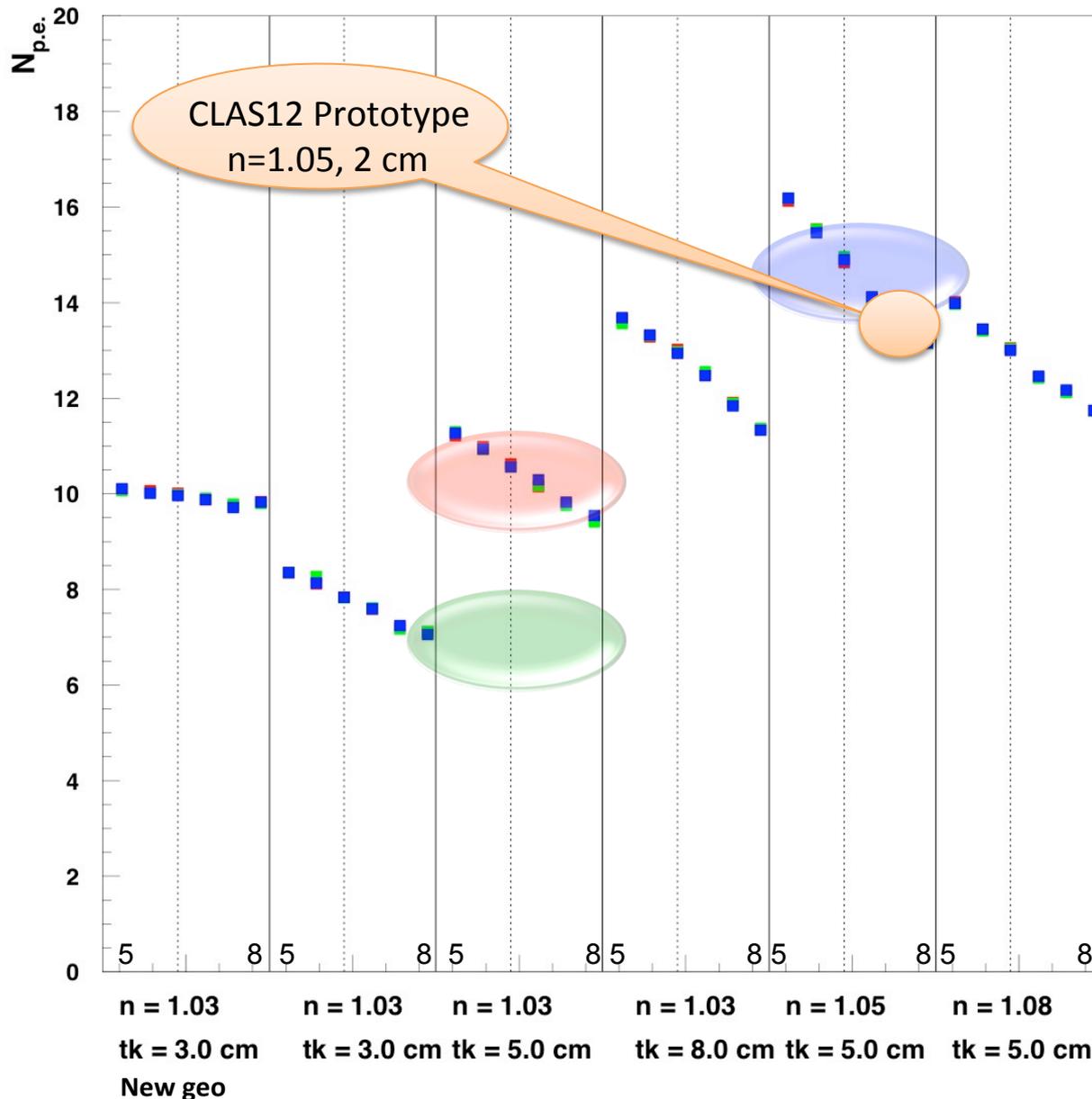
10 p.e. with aerogel of $n \sim 1.03$ refraction index and 5 cm thickness but lower transmittance

LHC-B

7 p.e. with aerogel of $n \sim 1.03$ refraction index and 5 cm thickness but 64% packing factor

P (GeV/c)

Mean p.e. Number (5-8 GeV/c)



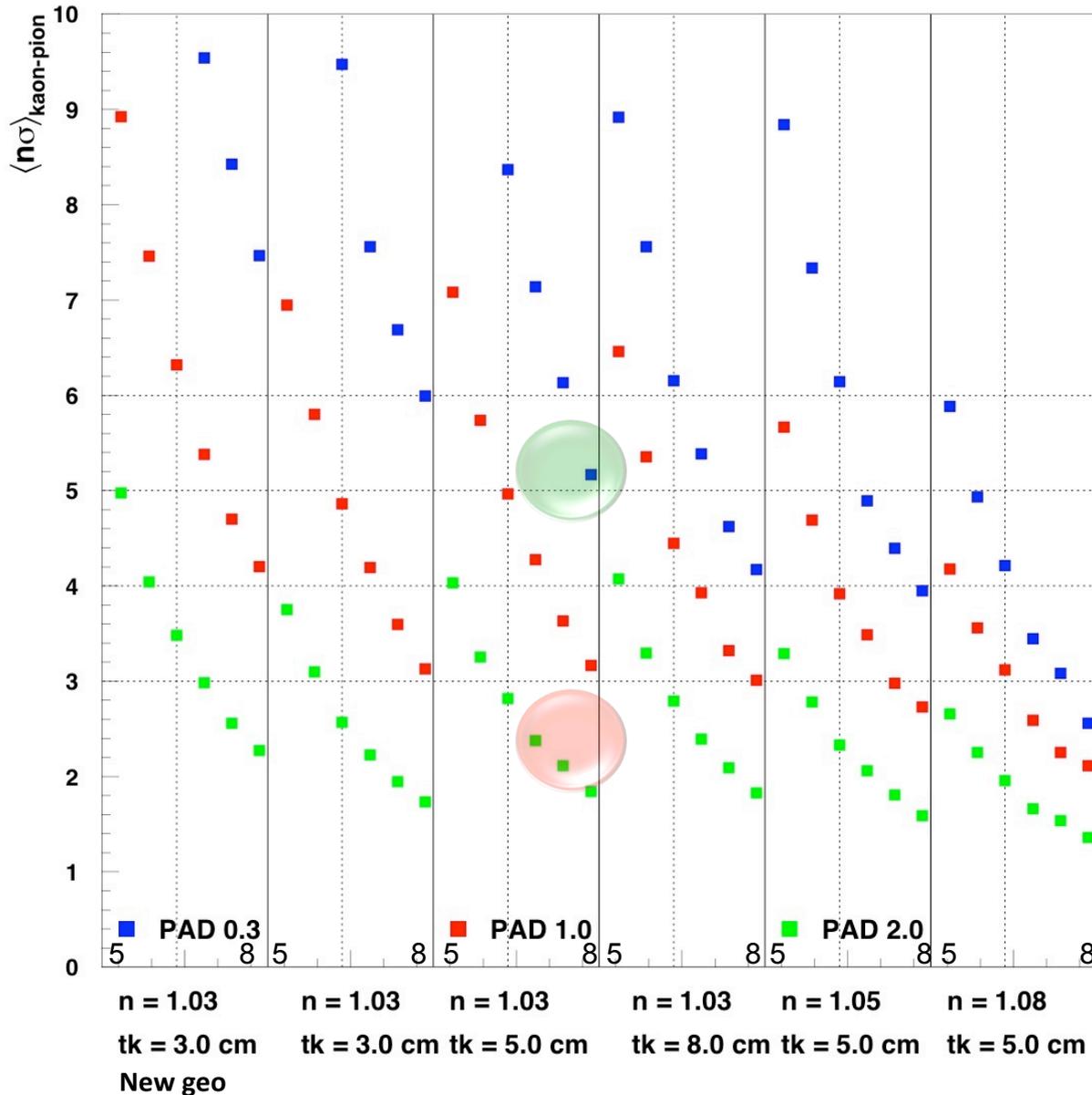
BELLE II test-bench
15 p.e. with aerogel of $n \sim 1.05$ refractive index and 4 cm thickness

HERMES experiment
10 p.e. with aerogel of $n \sim 1.03$ refraction index and 5 cm thickness but lower transmittance

LHC-B
7 p.e. with aerogel of $n \sim 1.03$ refraction index and 5 cm thickness but 64% packing factor

P (GeV/c)

Mean π/K Separation (5-8 GeV/c)



LHC-B

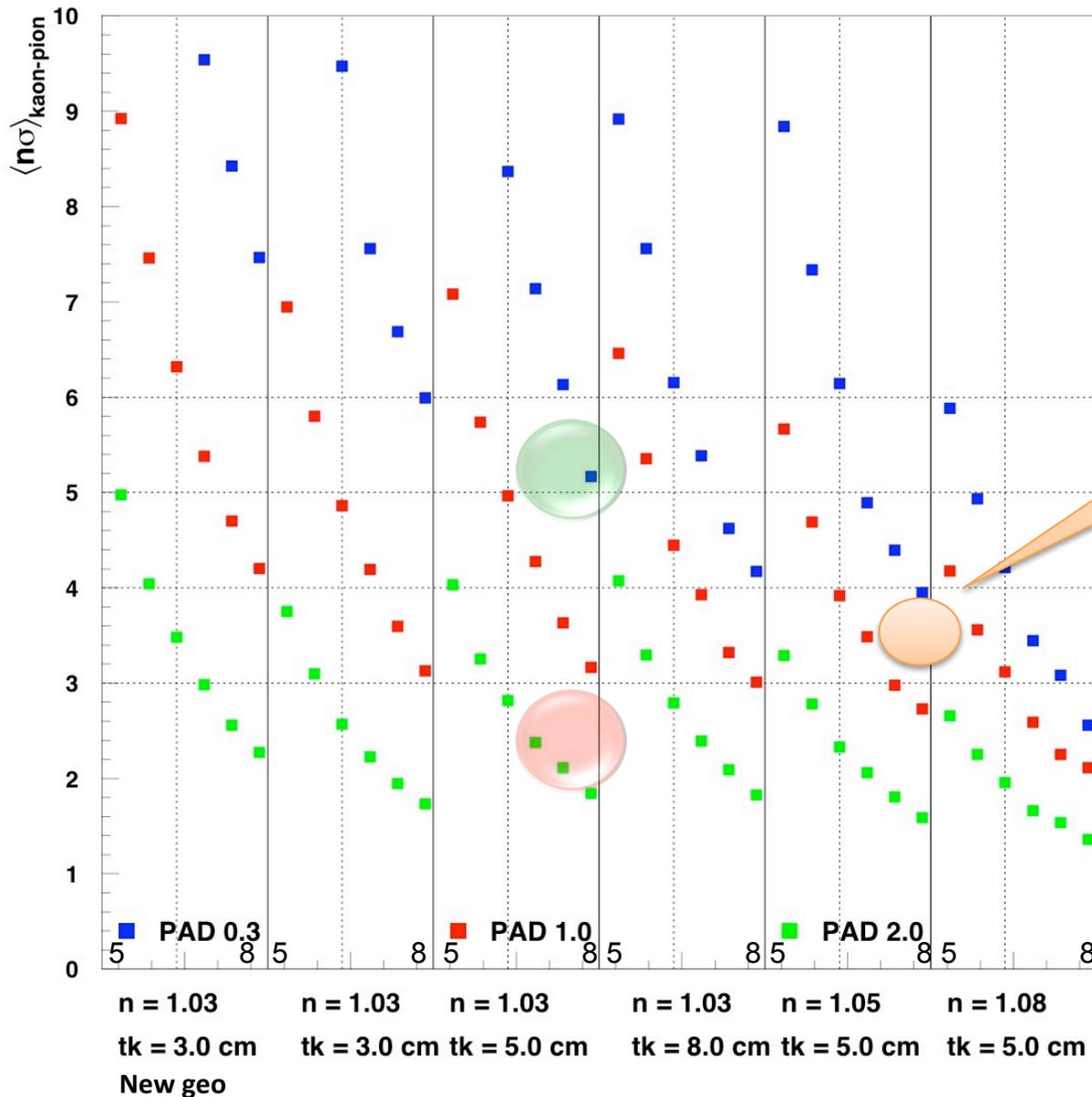
3 mrad single photon resolution with ~ 3 mm comparable pixel size

HERMES experiment

7.6 mrad single photon resolution, dominated by the ~ 2 cm pixel size

P (GeV/c)

Mean π/K Separation (5-8 GeV/c)



RICH Prototype
(M. Mirazita)

CLAS12 Prototype
n=1.05, 2 cm
6 mm pixel size

LHC-B

3 mrad single photon
resolution with ~ 3 mm
comparable pixel size

HERMES experiment

7.6 mrad single photon
resolution, dominated
by the ~ 2 cm pixel size

P (GeV/c)

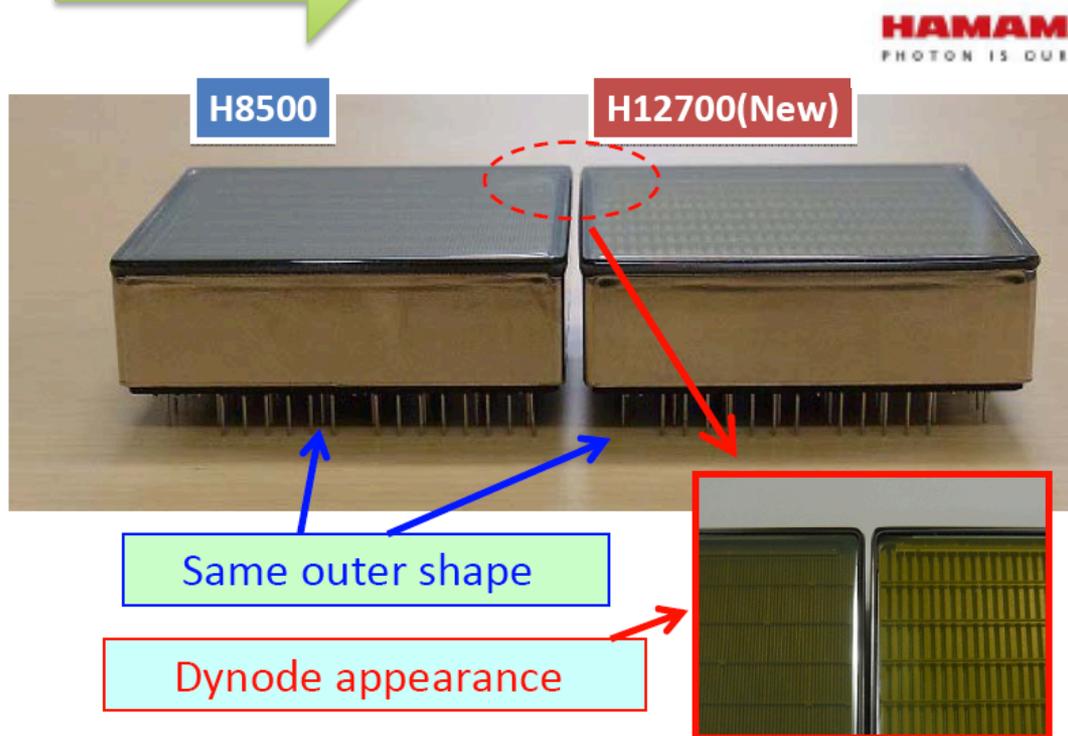
PHOTODETECTOR

Photon Detectors: MA-PMT

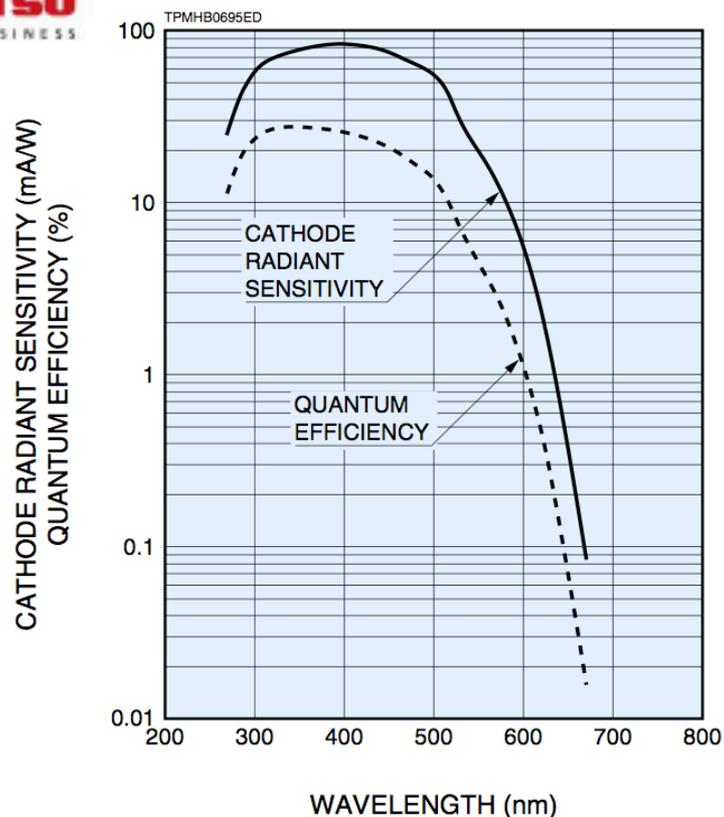
The only option to keep the schedule is the use of multi-anode photomultipliers (we consider the promising SiPM technology as the alternative)

- ✓ Mature and reliable technology
- ✓ Large Area ($5 \times 5 \text{ cm}^2$)
- ✓ High packing density (89 %)
- ✓ 64 $6 \times 6 \text{ mm}^2$ pixels cost effective device
- ✓ High sensitivity on visible towards UV light
- ✓ Fast response

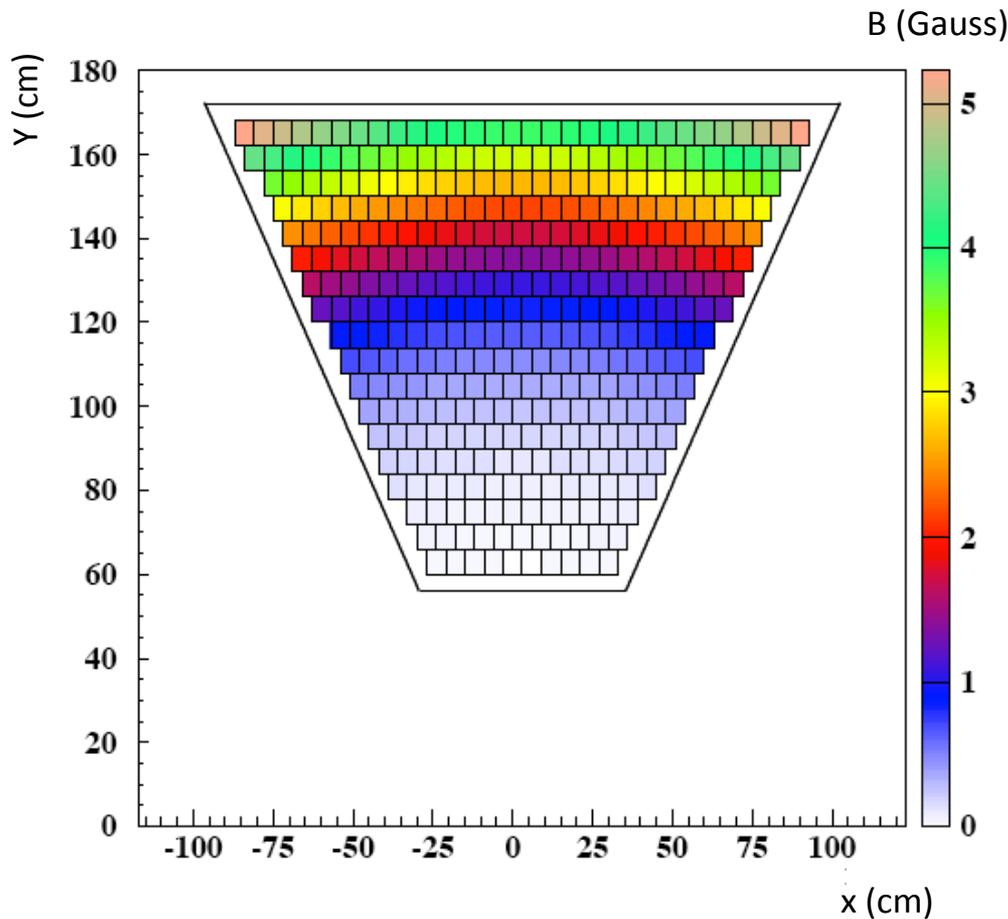
H8500 Tests
(M. Hoek)



Copyright © Hamamatsu Photonics K.K. All Rights Reserved

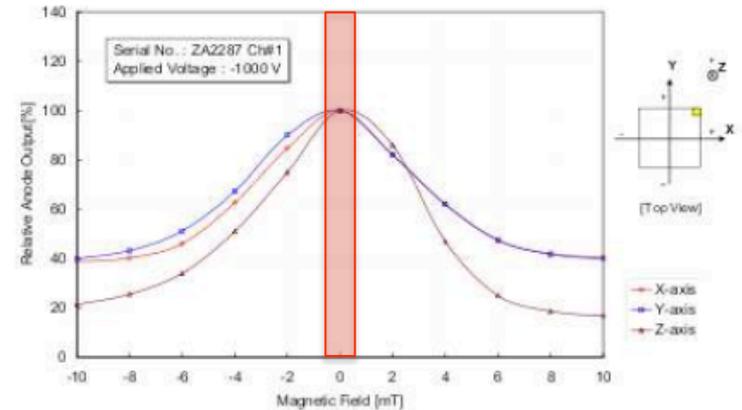


Magnetic Field



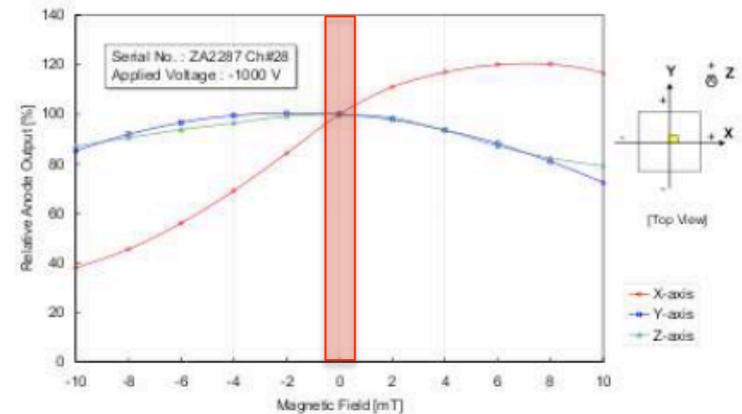
HAMAMATSU
HAMAMATSU PHOTONICS K.K. Electron Tube Division

H8500 Magnetic Field Characteristics



This information is furnished for your information only.
No warranty, expressed or implied, is created by furnishing
this information.

H8500 Magnetic Field Characteristics



The torus fringe-field allows the use of Multi-Anode Photomultipliers

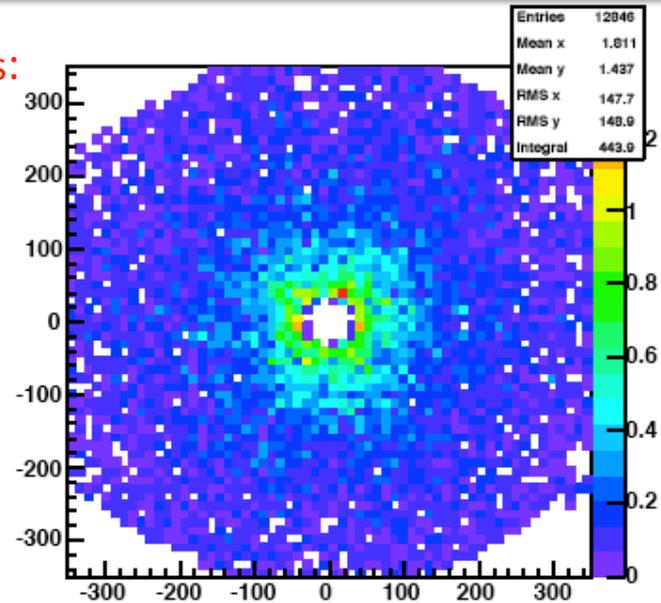
Radiation Damage: Neutrons

Measured fluence @ Belle:
90/fb \rightarrow 1-10 10^9 n/cm²

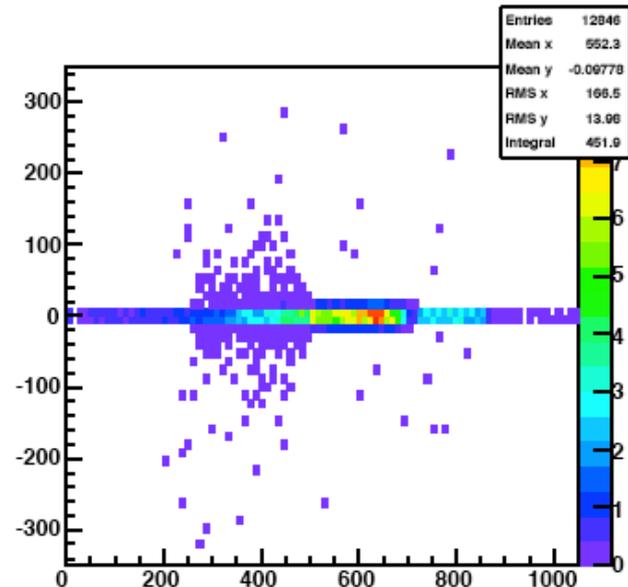
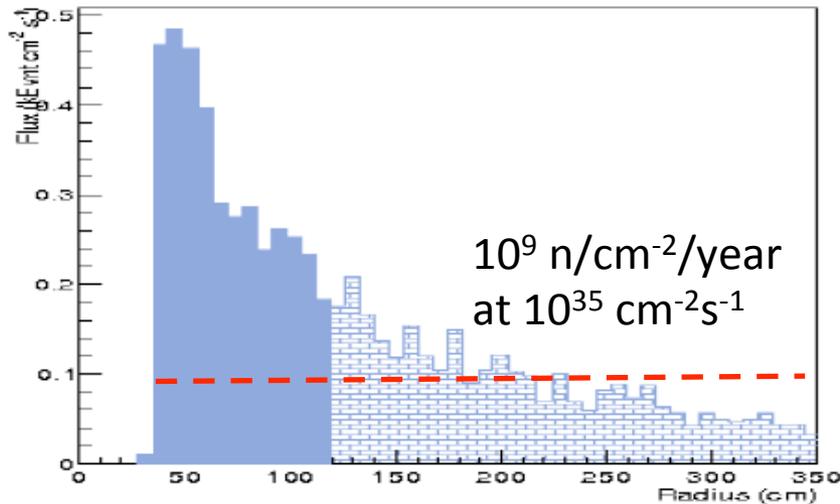
Expected fluence @ Belle-2:
50/ab \rightarrow 2-20 10^{11} n/cm²

Expected fluence @ LHCb-2:
1 year \rightarrow 6 10^{11} n/cm²

Neutrons:

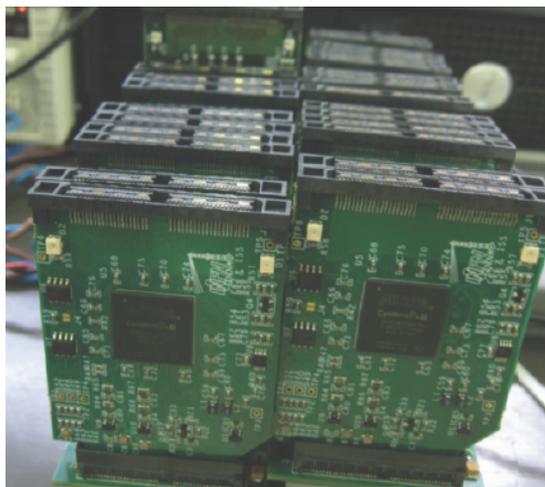


Neutrons:



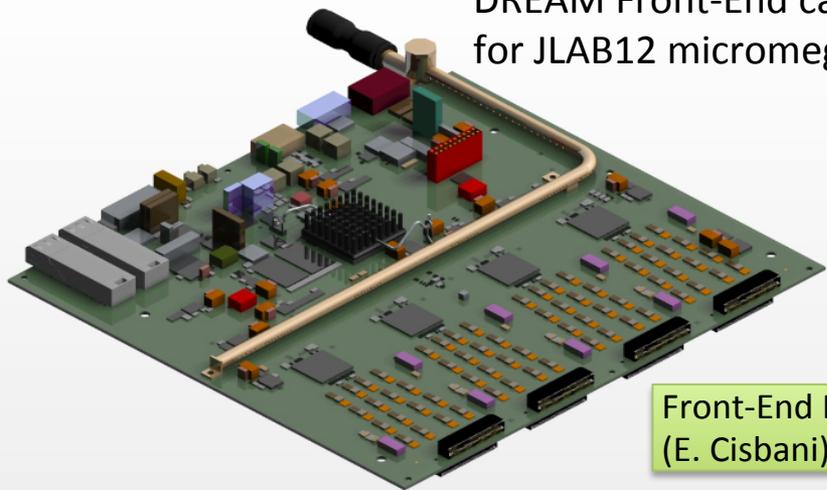
MA-PMTs Readout

MAROC3 Front-End card with digital and analog readout tested with the prototype



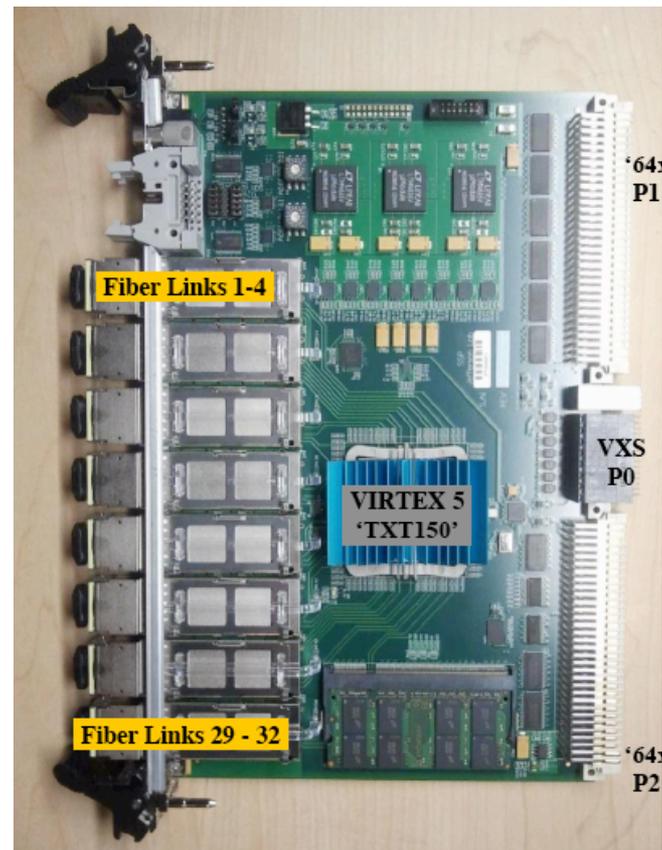
Basic components with already existing designs and prototypes

DREAM Front-End card developed for JLAB12 micromegas readout



Front-End Electronics
(E. Cisbani)

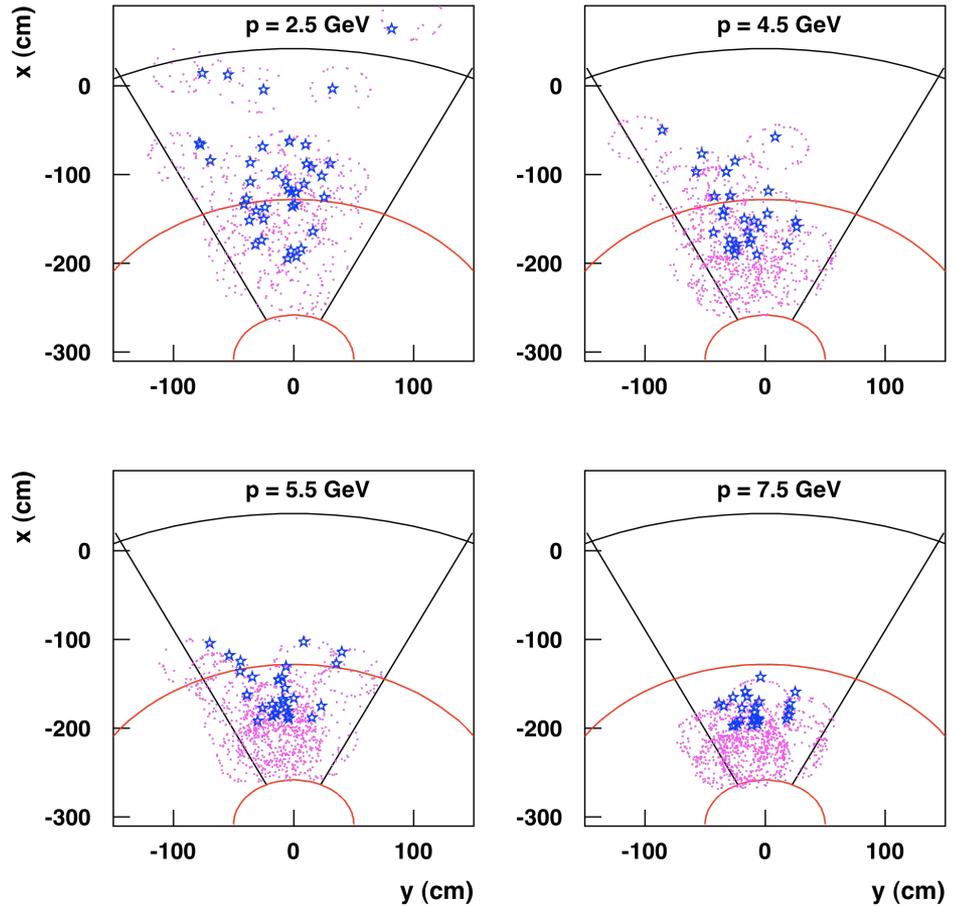
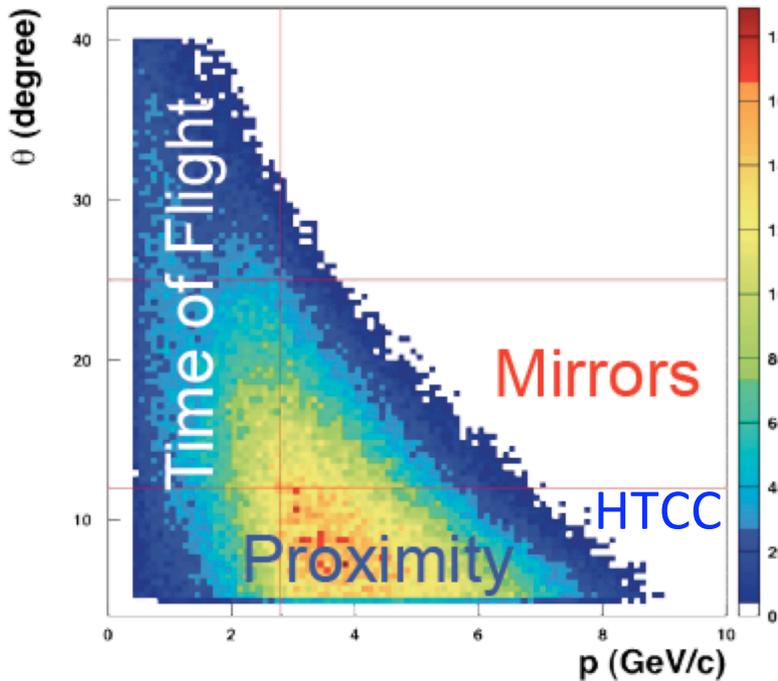
VME DAQ Optics FPGA module
Developed for GLUEX and JLAB12



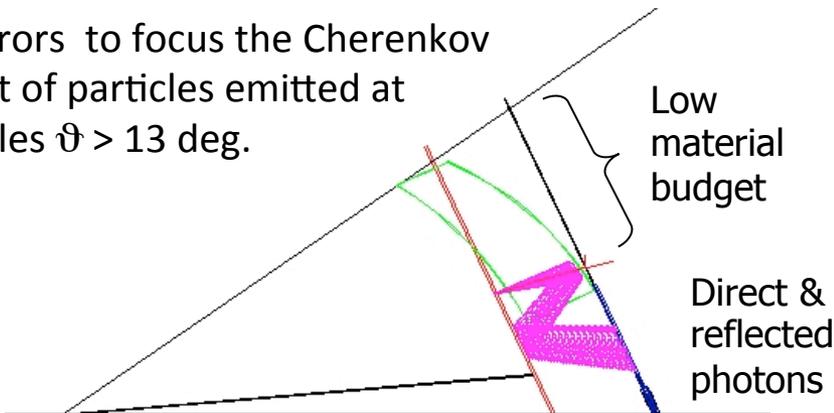
DAQ and Trigger
(C. Cuevas)

THE MIRROR SYSTEM

The Mirror System



Mirrors to focus the Cherenkov light of particles emitted at angles $\vartheta > 13$ deg.

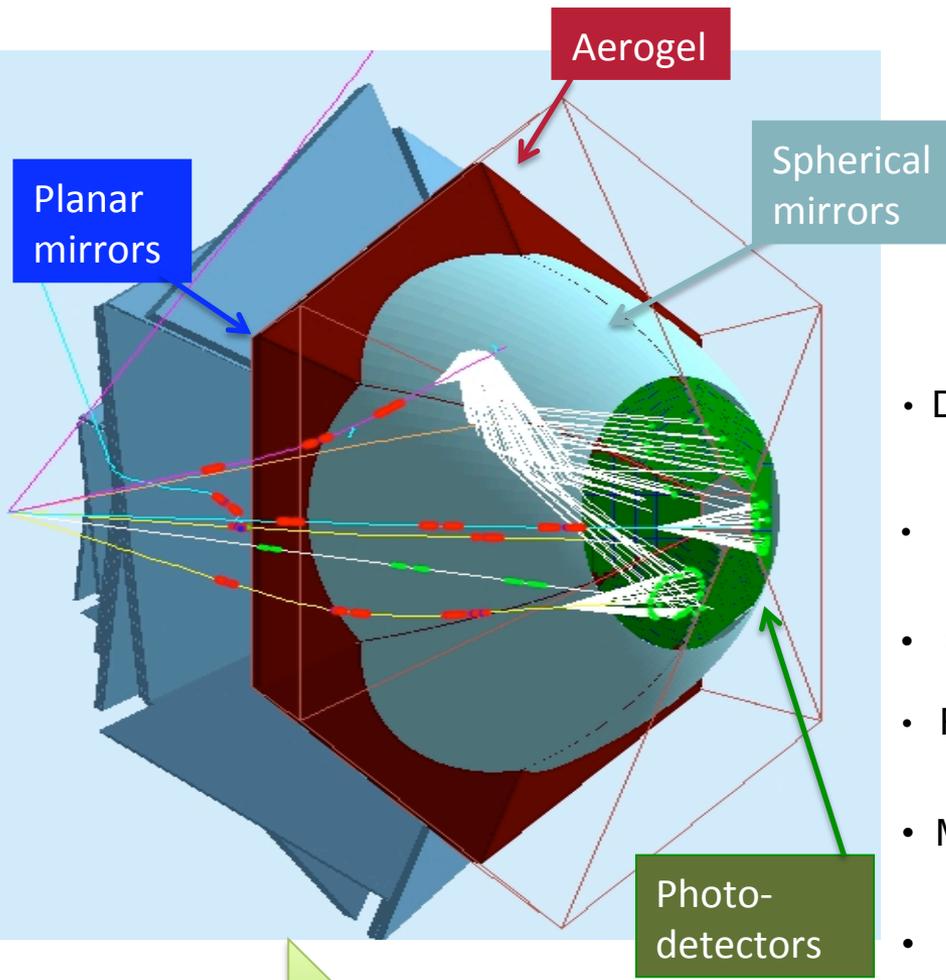


Goals:

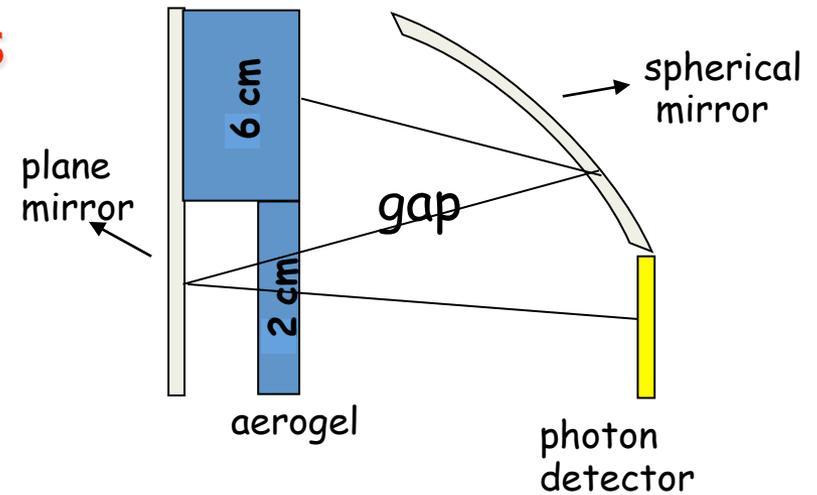
- instrument only forward region
- reduce active area ($\sim 1 \text{ m}^2/\text{sector}$)
- minimize interference with TOF system

The Mirror System

Proximity Focusing RICH + Mirrors



Integration in CLAS12
(M. Contalbrigo)



- Direct rings for high momentum particle
→ best performance !
- Minimize photon detector area → cost !
- **Open detector close to beam line → background !**
- Reflected rings for low momentum particle
→ less demanding
- Minimum interference with TOF
- **Multiple passages within aerogel → photon losses**
- Focalising mirrors allow for thicker aerogel
(to partly compensate the loss of photons)

Mirror Technology

Metalized Carbon Fiber substrate
for spherical mirror

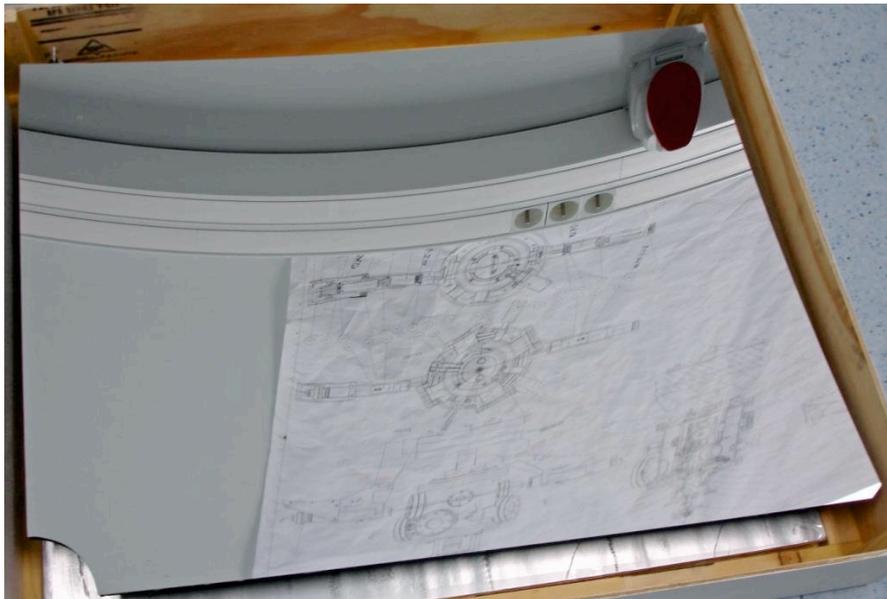
Self-supporting structure with
minimal material budget
(applications in physics experiments)

standard technologies already in use and commercially available

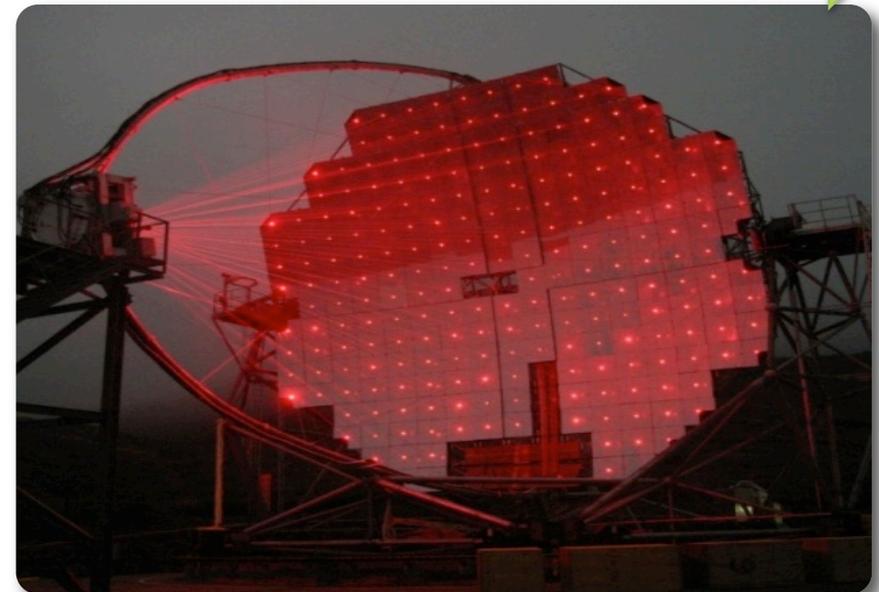
Thin glass skin on a flat support
for planar mirrors

Cost-effective technology for precise
large area mirrors
(applications in terrestrial telescopes)

Mechanical Design
(S. Tomassini)



LHCB mirror



MAGIC-II telescope

RICH Project Achievements

2010:

- ✓ Concept of Design and Technology

2011:

- ✓ Tests of components and small prototype

2012:

- ✓ July: Test-beam with Electrons (Frascati)
- ✓ July: Test-beam with Hadrons (CERN)
- ✓ December: Test-beam with Hadrons (CERN)

2013:

- ✓ February: Start Engineering Phase
- ✓ 26-27 June: Technical Review

Technical Review Recommendations

1) We recommend that a full Monte Carlo of CLAS with a RICH sector be developed. A report should be generated for review by CLAS management to document the simulation and the expected performance of CLAS with a RICH, both the enhanced performance in Kaon separation as well as the extent of any degradation in the response of other CLAS components.

A full RICH simulations was implemented in the CLAS12 GEMC simulation platform under construction: the result are reported in chapter 13 of TDR and in the “Integration in CLAS12” talk.

2) We recommend that at least average properties such as index of refraction, transmission and clarity be measured and recorded for each tile prior to installation. We recognize the added potential challenge to the tight time constraints and urge the collaboration to develop procedures required to expedite such a chain of measurements.

3) We recommend that, given the large tile size, the variation of the index of refraction across a tile be measured for a sample of tiles, and the typical variation be included in the RICH Monte Carlo.

The procedures are under test and definition and described in chapter 3 of TDR and in the “Aerogel Tests” talk: a semi-automatized characterization of each tile is foreseen.

Technical Review Recommendations

4) We recommend that the collaboration obtain samples of Novosibirsk tiles fabricated with smooth planar surfaces and assess their optical properties.

A new dedicated production will start beginning of September 2013.

5) We recommend that the collaboration investigate the potential background from scintillations in the gas within the RICH chamber and the affect on the Aerogel of any mitigating measures.

We estimate a manageable maximum 4 p.e. background for a 1m pure-N₂ gap.
An even smaller yield is expected with dry air or CO₂

6) We recommend that a Finite-Element-Analysis (FEA) be undertaken for the entire detector, considering all loads generated in transport, installation, and maintenance.

The analysis was done for the RICH structure, the mirrors and aerogel supports for different orientations of the RICH sector as reported in chapter 10 of TDR and in the “Mechanical Design” talk. Dedicated transport and installation procedures will be finalized in parallel with the mechanical design.

Technical Review Recommendations

7) We recommend that the collaboration focus R&D efforts to develop a reliable time line that leads to a mirror system which can be adequately characterized prior to installation.

We adopt standard technologies commercially available. The construction plan is discussed in the “Project Management” document and talk.

8) We recommend that aging studies be initiated to check the long-term effects on the dark current of the H8500 when operated at 1075 V.

To run at 1075 V is not anymore required thanks to an improvement of the MAROC3 front-end card. Aging tests are anyway planned in September 2013.

9) We recommend that a procedure be developed to provide some characterization of the pixel by pixel response of each MAPMT, possibly through a gain measurement in response to uniform illumination.

An automatized pico-second laser test bench is already in operation as shown in chapter 7 of TDR and in the “H8500 Tests” talk. An online pixel by pixel gain calibration is foreseen by analog readout of SPE dark counts, see chapter 8 of TDR and Front-End electronics talk.

Technical Review Recommendations

10) We recommend that the collaboration analyze and adopt a firm decision date, at which point they revert to H8500 MAPMTs, at least for this first RICH sector, if Hamamatsu cannot demonstrate mass production of H12700 units.

The chosen deadline (1st February 2014) accounts for the H12700 estimated production time as discussed in the “Project Management” talk.

11) We recommend that the collaboration develop a full plan for the readout and DAQ with a cost analysis to identify responsibilities for design, construction and implementation.

The task sharing between INFN (Front-End) and JLab (DAQ) optimizes the complementary competences. Cost analysis and construction plan are discussed in the “Project Management” document and talk.

12) We recommend that Jlab/Hall-B provide a defined volume for the RICH detector, including available cooling and cabling spaces, as well as defining the required attachments to the forward carriage.

The RICH is design to fit into the LTCC clearance and weight with same joints to the forward carriage, as discussed in chapter 10 of TDR and “Mechanical Design” talk. The service (HV and LV cabling, readout optical fibers and gas lines) route and connectors along the torus coil shadow mimic the ones of LTCC.

Technical Review Recommendations

13) We recommend that Jlab/Hall-B provide a suitable limiting temperature in the region of the FTOF and that the collaboration demonstrate by calculation that this limit can be held. Suitable steps should be taken to protect against a failure of the airflow.

The power consumption of the readout electronics (~400 W) is discussed in chapter 8 of TDR and in the “Front-End” talk. Standard temperature mitigating measures and slow-control monitors exist, as shown in chapter 10 of TDR and “Mechanical Design” talk.

14) We recommend that the collaboration develop a detailed work-breakdown that includes the resources required for each step in order to track closely the schedule.

The Project Plan is ready and discussed in the “Management Plan” document and talk.

RICH outlook

Summer 2013:

- ✓ August: Finalize CLAS12 RICH Project (TDR)
- ✓ August: Finalize Project Management Plan
- ✓ 5-6 September: Project Review with DOE
- ✓ September: Ready for Construction



Management Plan
(P. Rossi)

GOAL: 1st sector ready by the end of 2016