# RICH Project Overwiev

Contalbrigo Marco
INFN Ferrara

Rich Project Review, 5th September 2013

# The CLAS12 Spectrometer

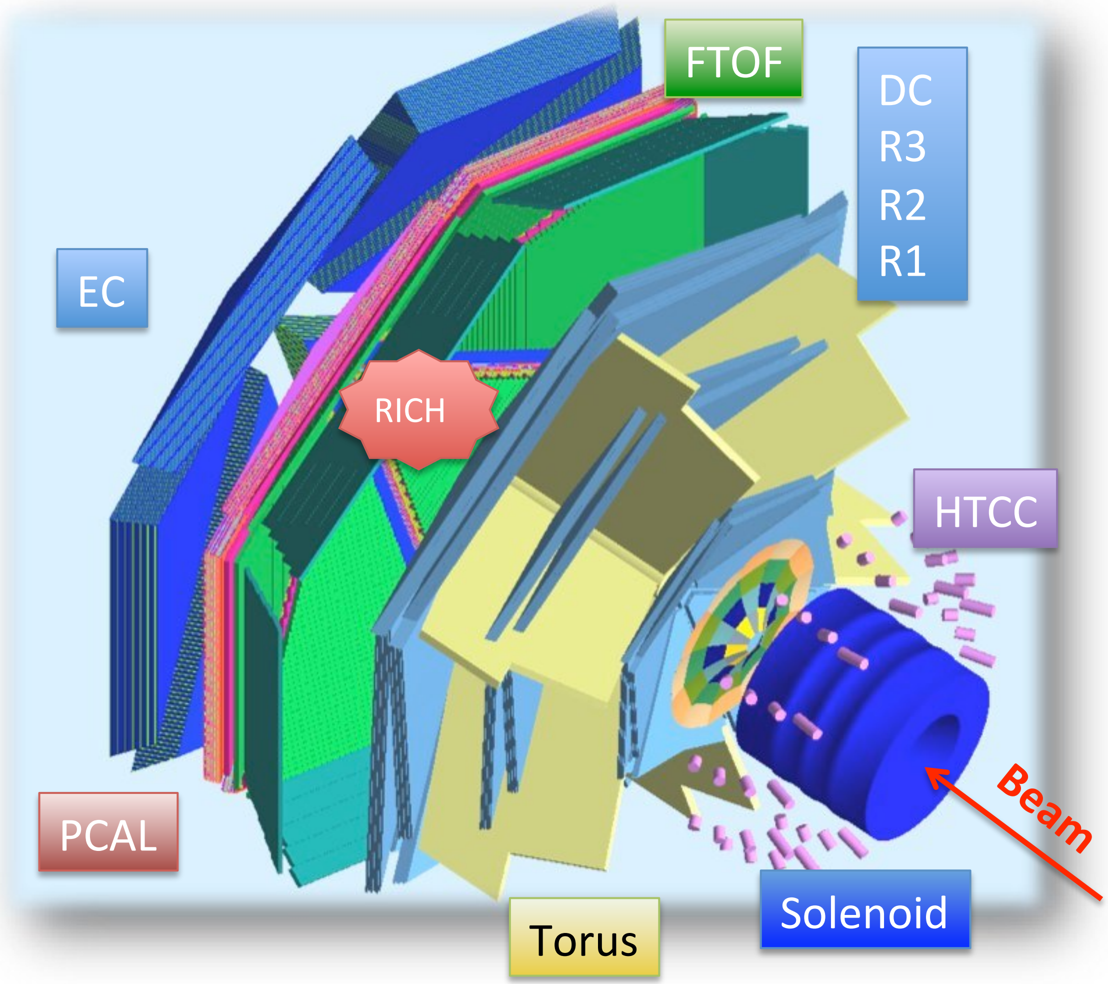
Luminosity up to $10^{35}$ $cm^{-2}$ $s^{-1}$

Highly polarized electron beam

H and D polarized targets

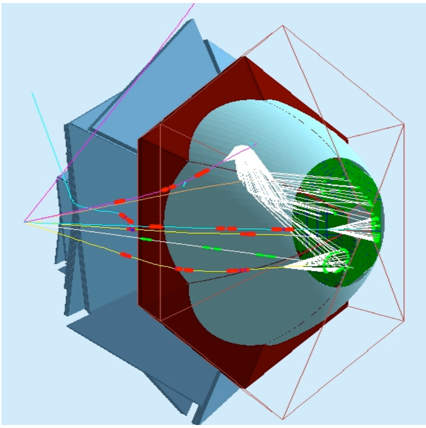
Broad kinematic range coverage
(current to target fragmentation)

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

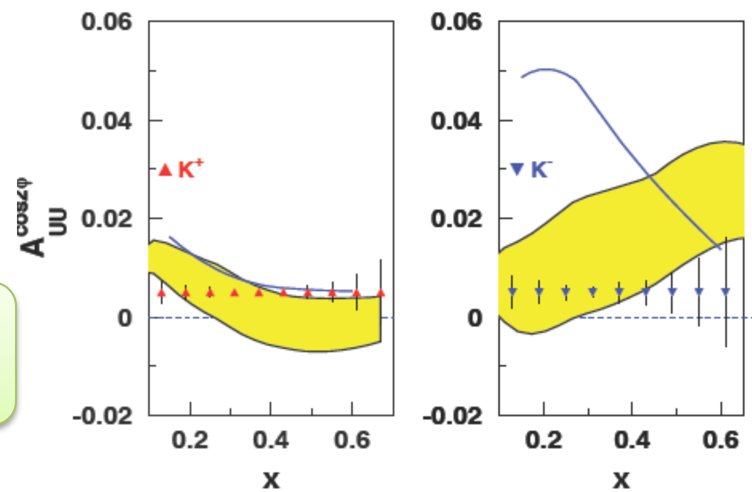



PAC30 report (2006): Measuring the kaon asymmetries is likely to be as important as pions …. The present capabilities of the present CLAS12 design are weak in this respect and should be strengthened.

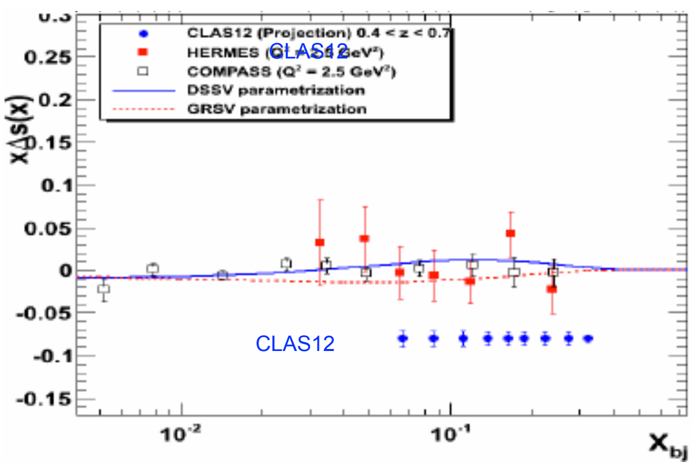
# Kaon SIDIS Program @ CLAS12



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

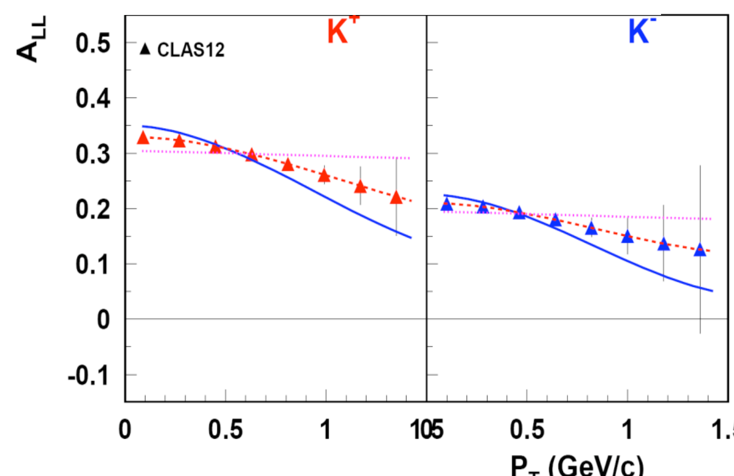



RICH detector for flavor separation of quark spin-orbit correlations in nucleon structure and quark fragmentation




**E12-09-09:**

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

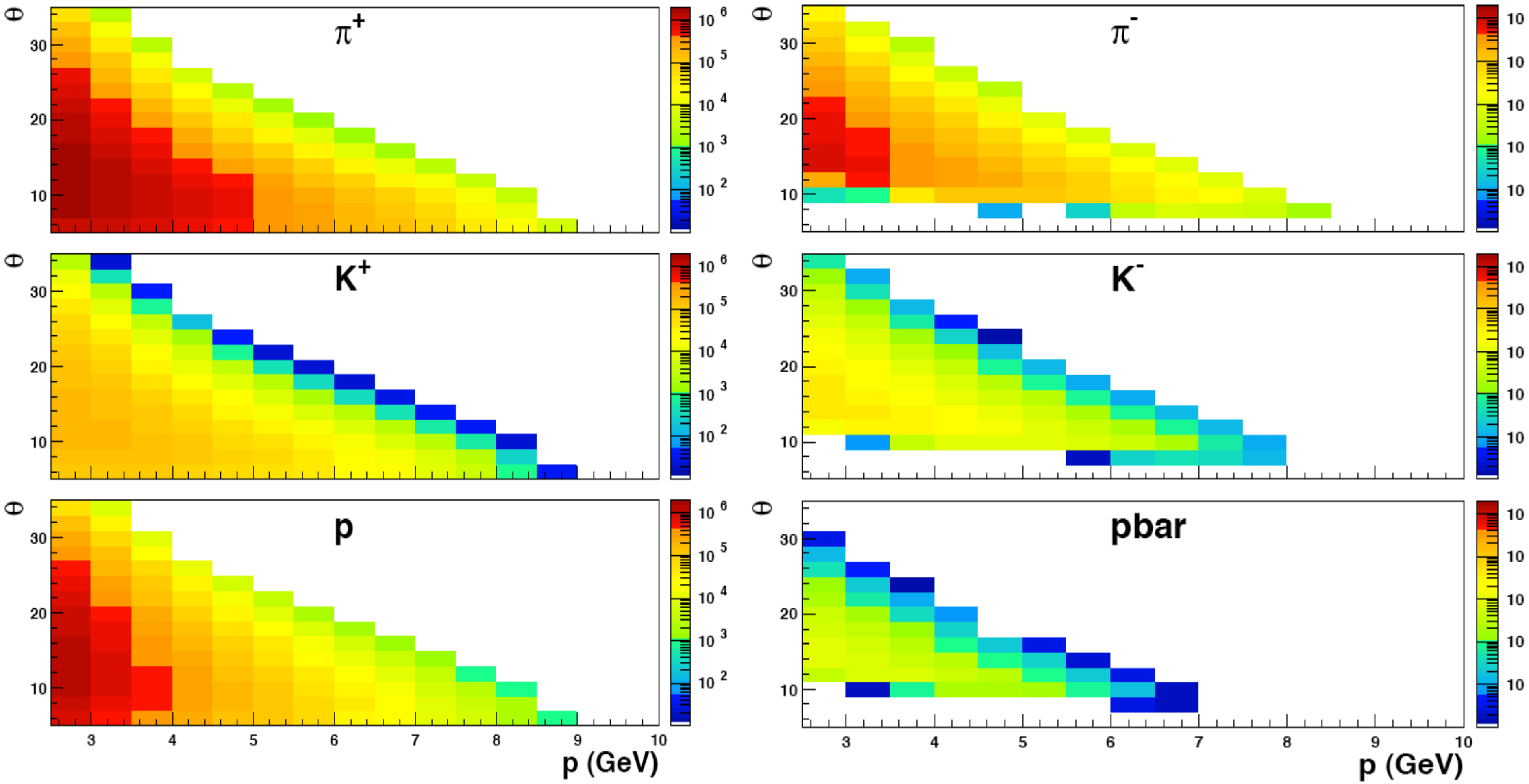



**E12-09-07:**

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

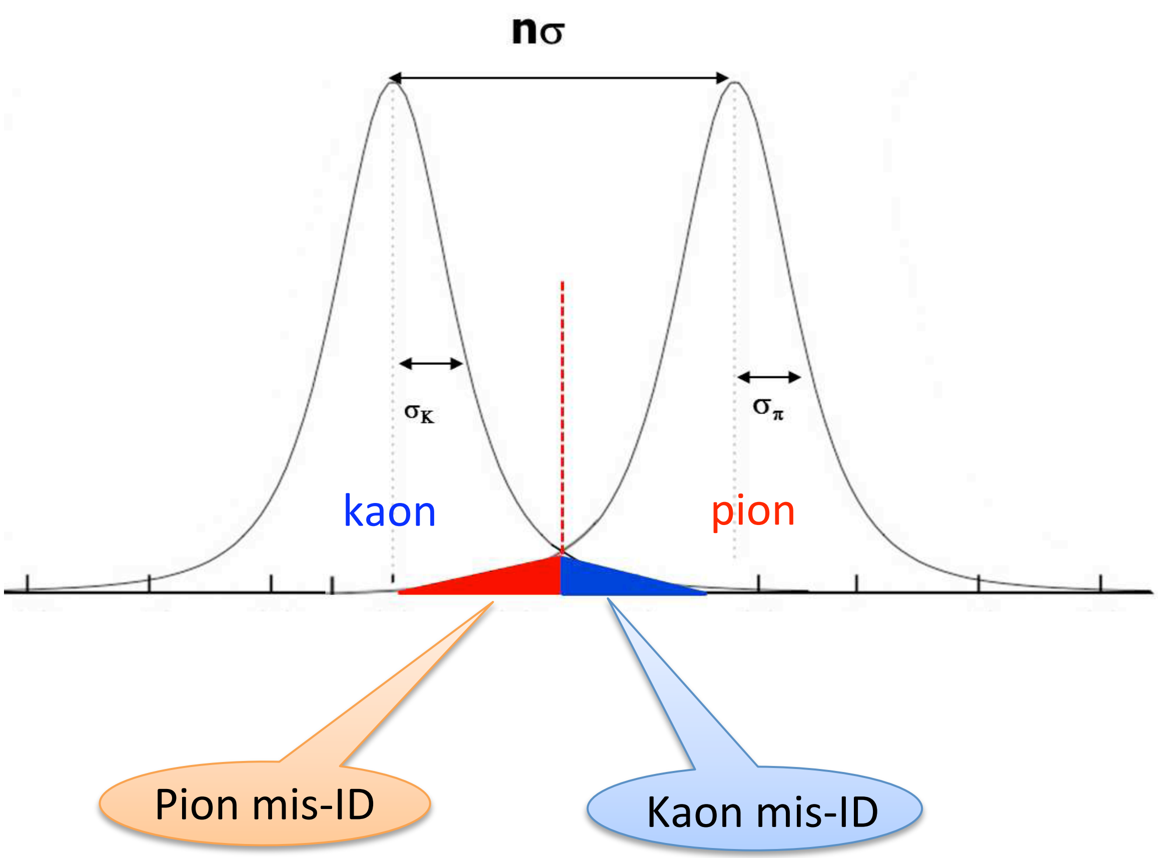


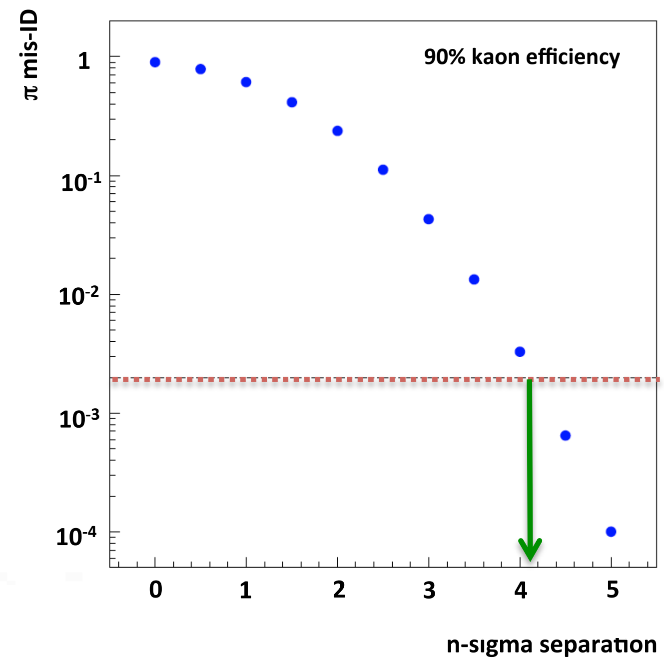

Out-bending particles

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



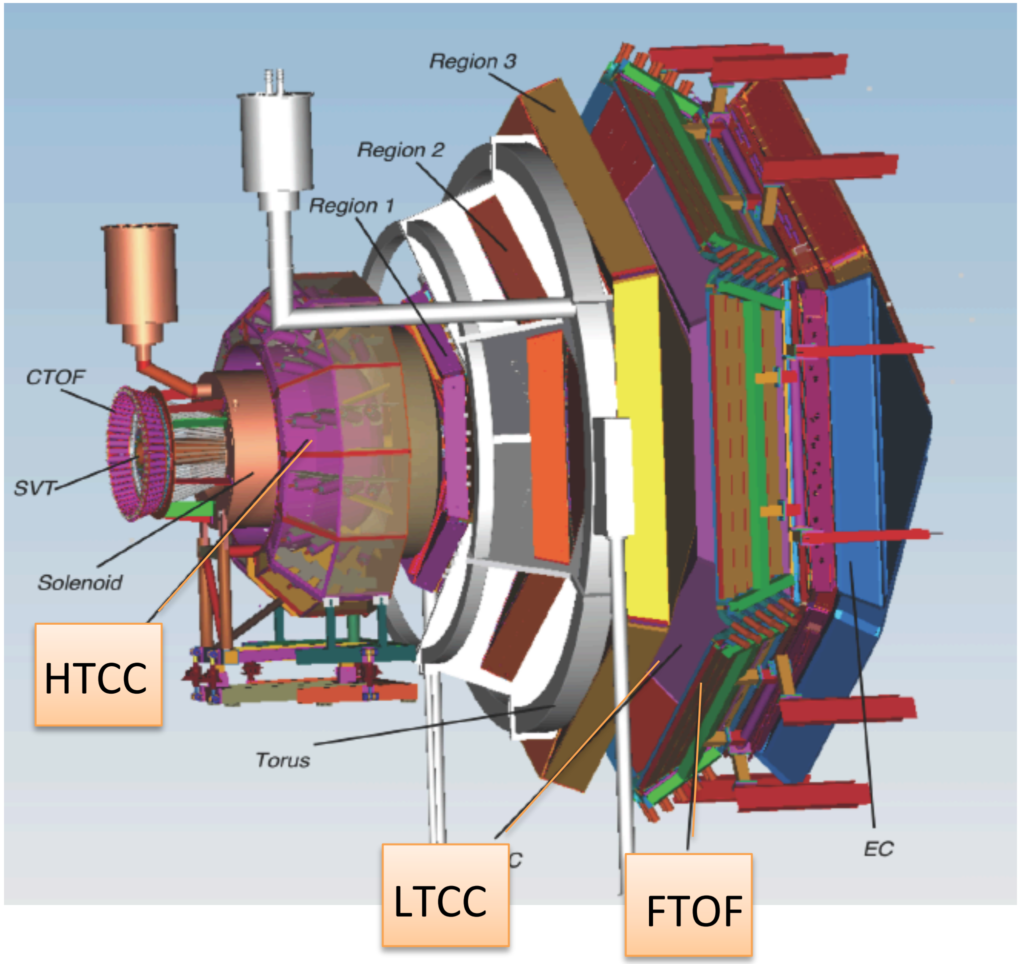



# Baseline PID @ CLAS12

**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

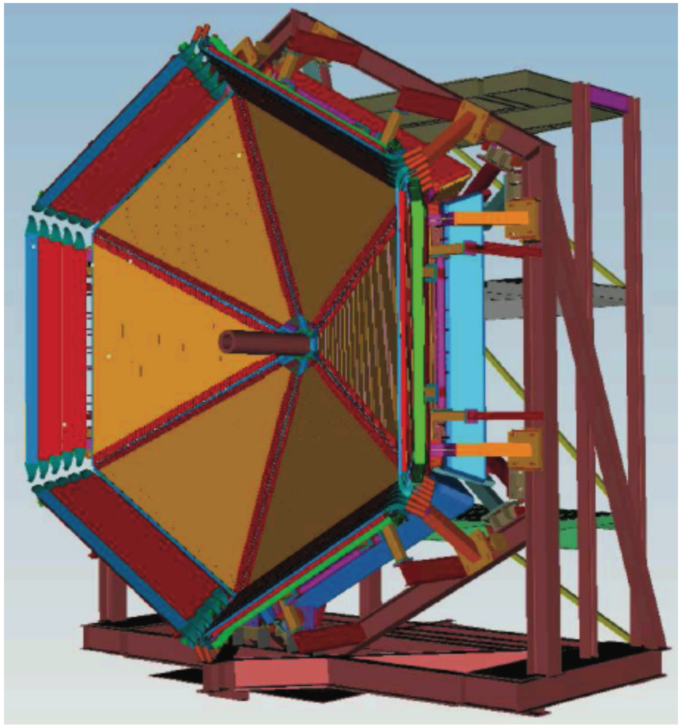


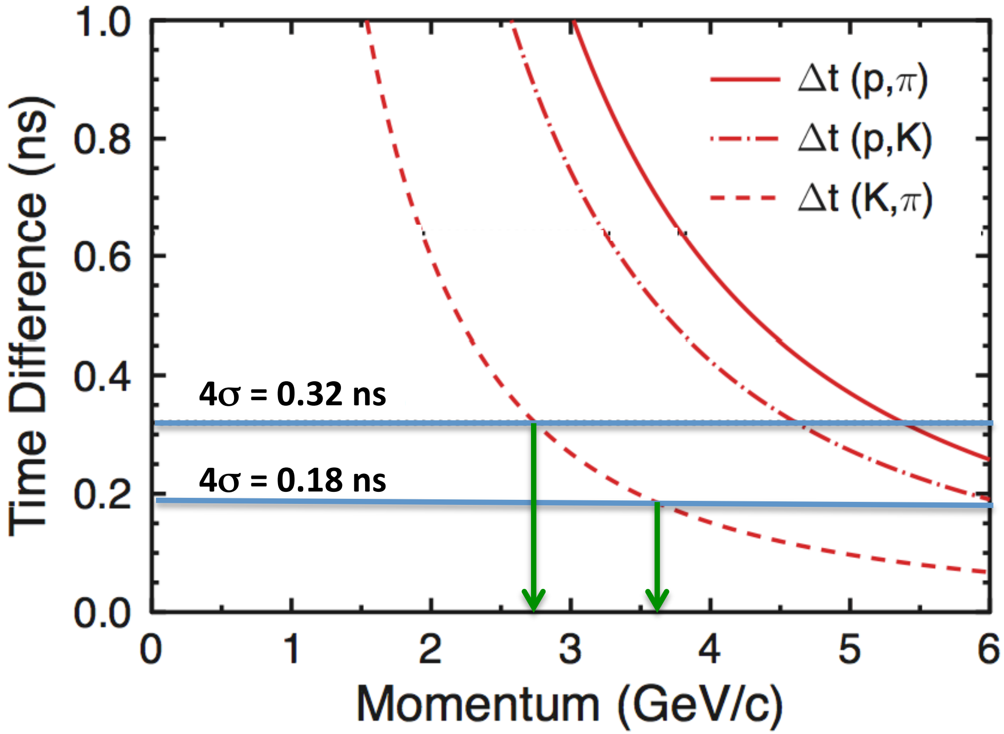
# FTOF @ CLAS12

Two scintillators 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





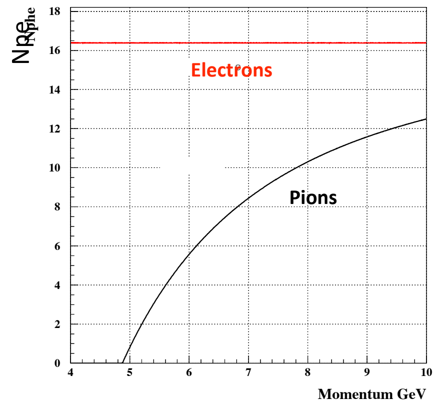

Suitable hadron separation achieved by time-of-flight at 650 cm from IP:

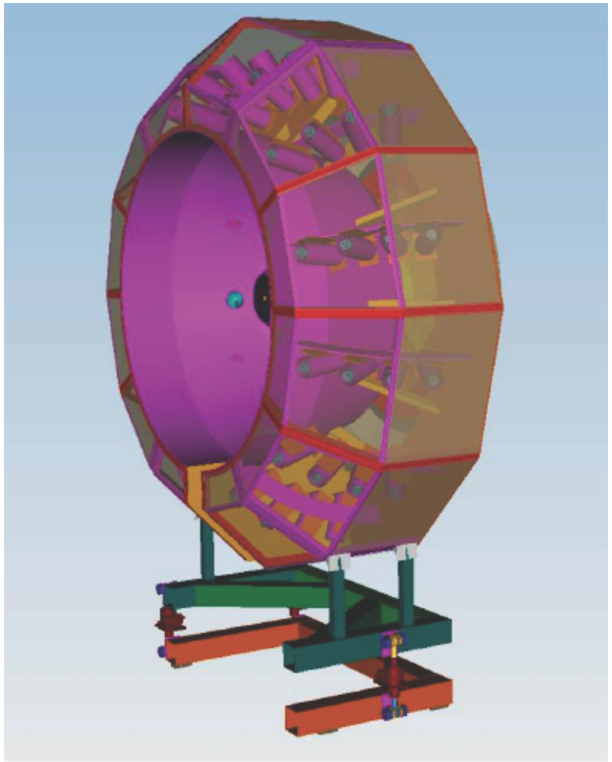
Up to 2.8 GeV/c (θ = 36 degrees)
Up to 3.6 GeV/c (θ = 5 degrees)

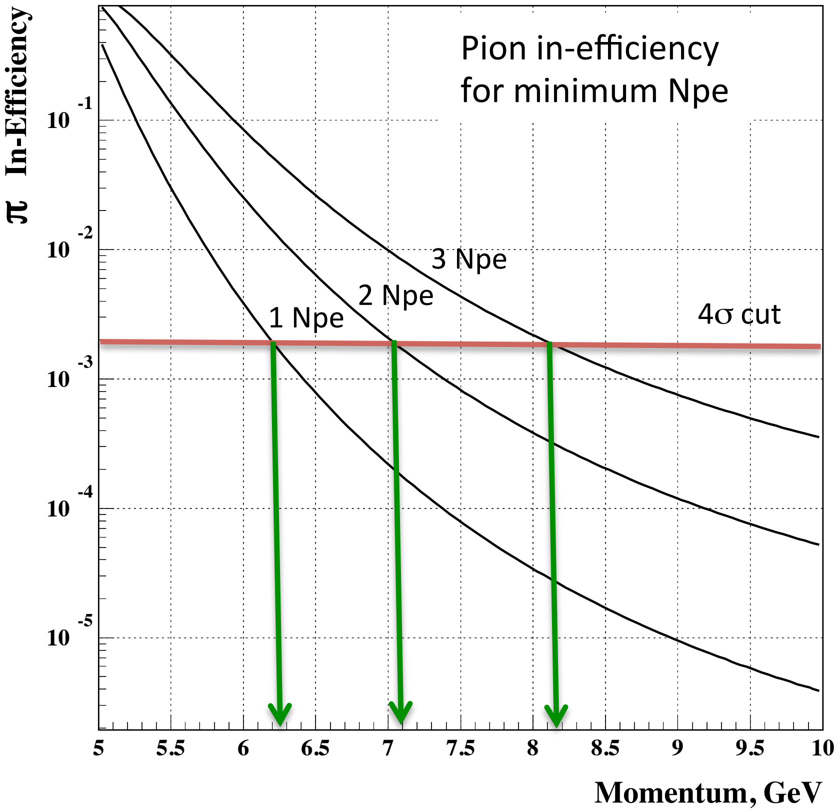
New detector for electrons ID:

$CO_2$ 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

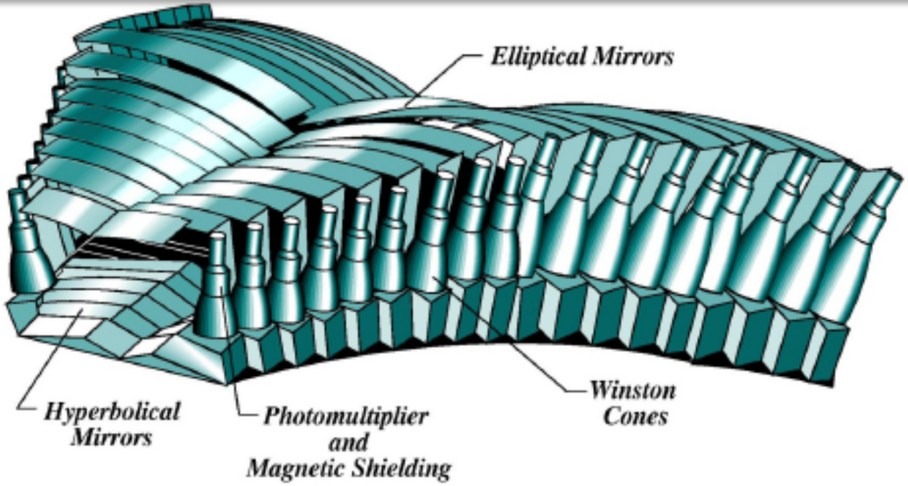
~ few per mil above 7 GeV/c

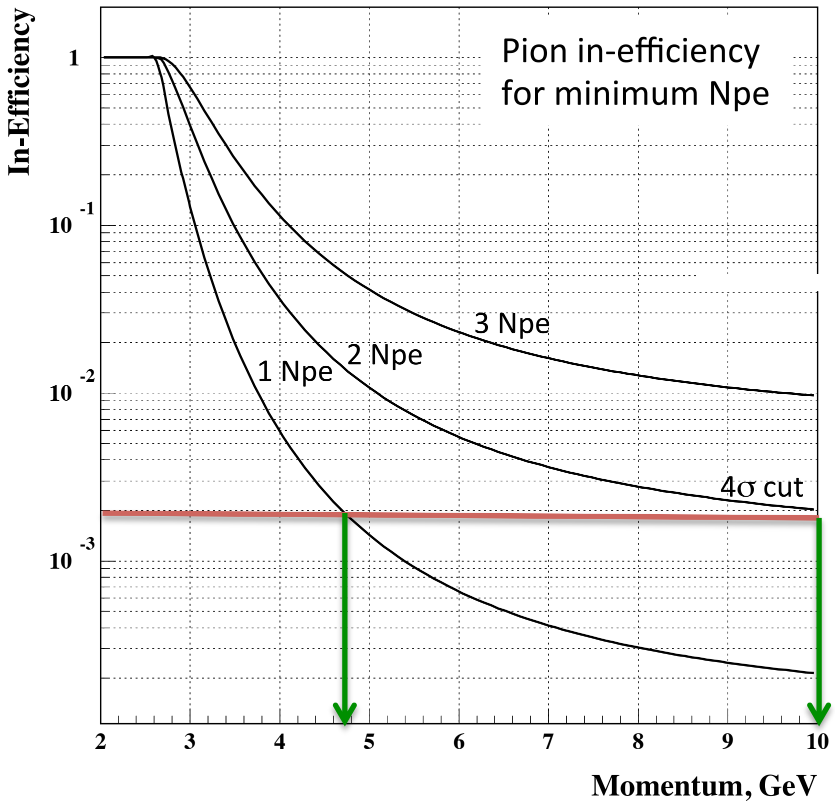
Requested pion separation achieved above 7 GeV/c
No kaon-proton separation

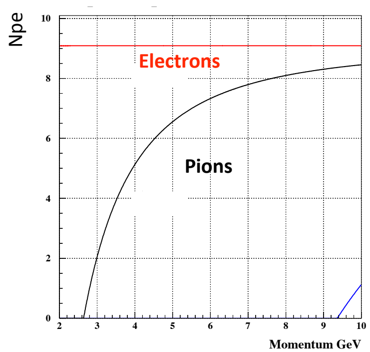
Derived from CLAS for pion ID:

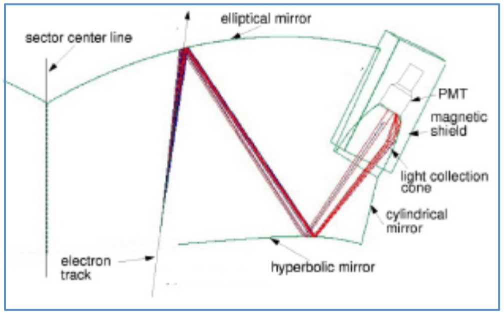
$C_4F_{10}$ radiator
Complicated design with irregular response
Limited $\phi$ acceptance

Expected p.e. number with electrons ~ 9




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

100 % below 2.7 GeV/c (Cherenkov threshold)

~ % level around 5 GeV/c

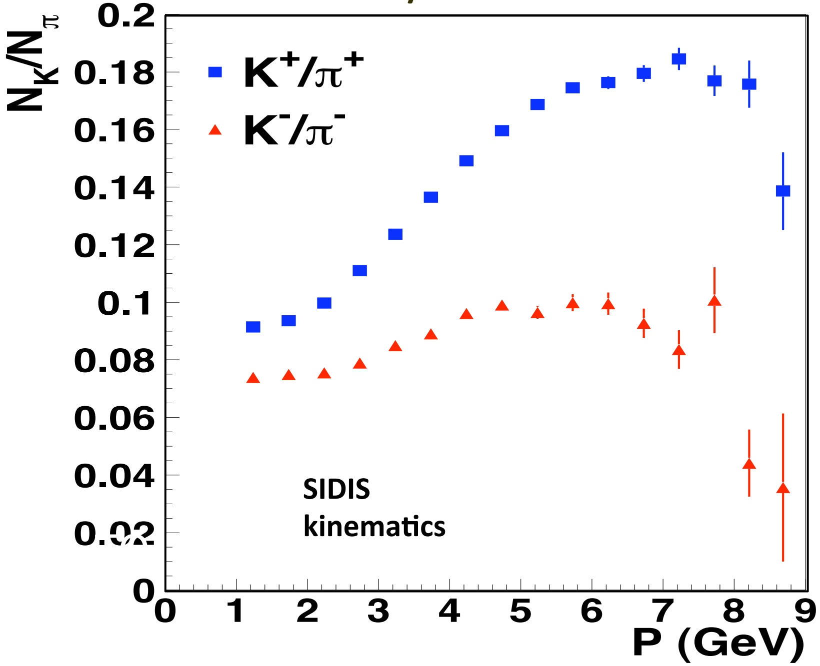
~ per mil level above 7 GeV/c

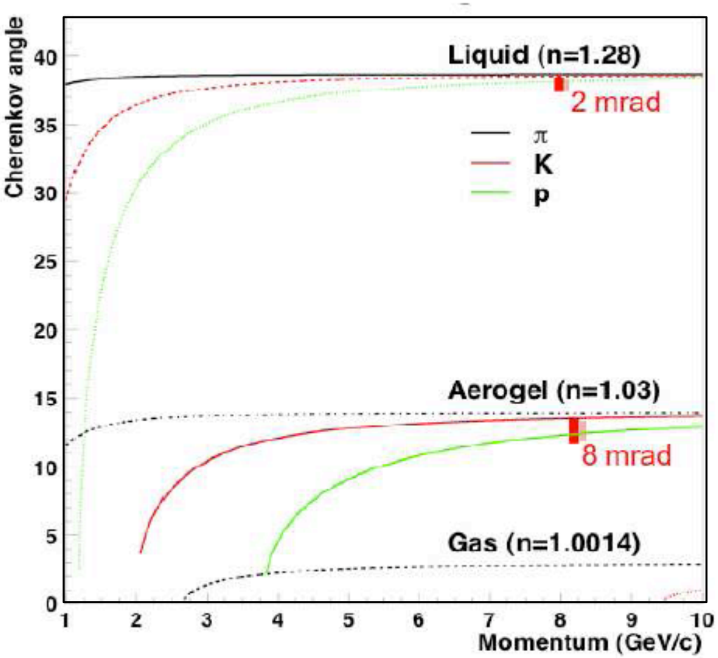
Requested pion separation achieved above 8 GeV/c
No kaon-proton separation

# 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

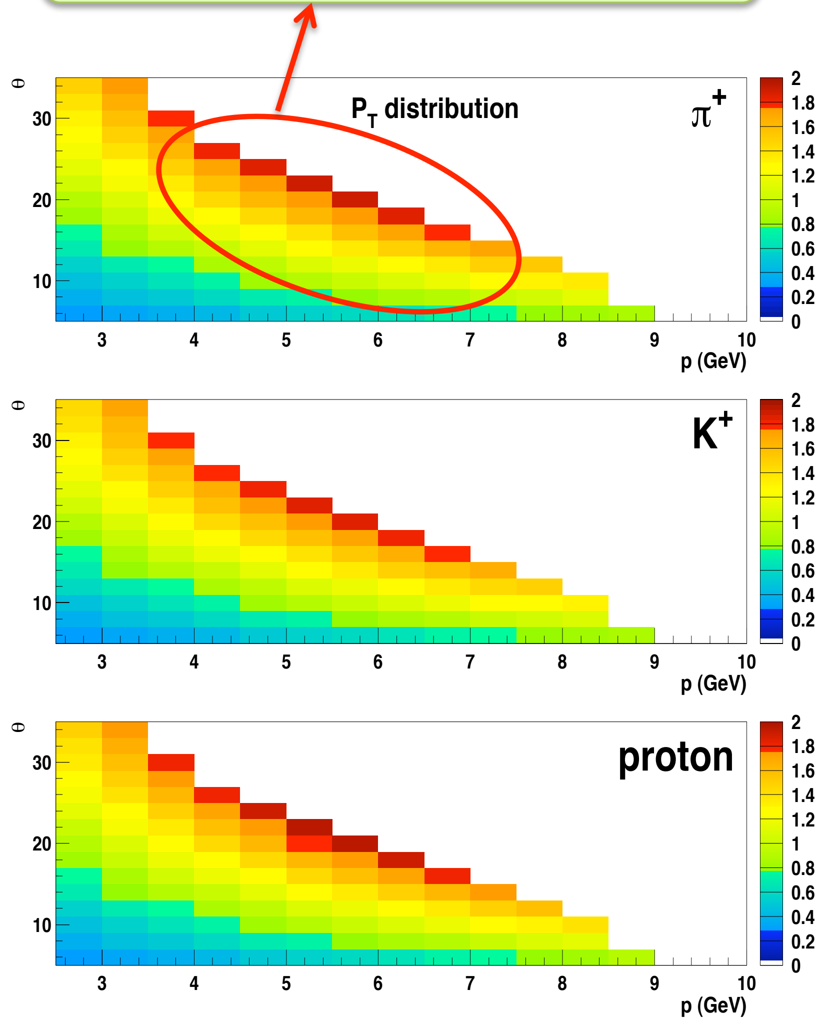
**Ratio K/π ~ 0.1-0.15**



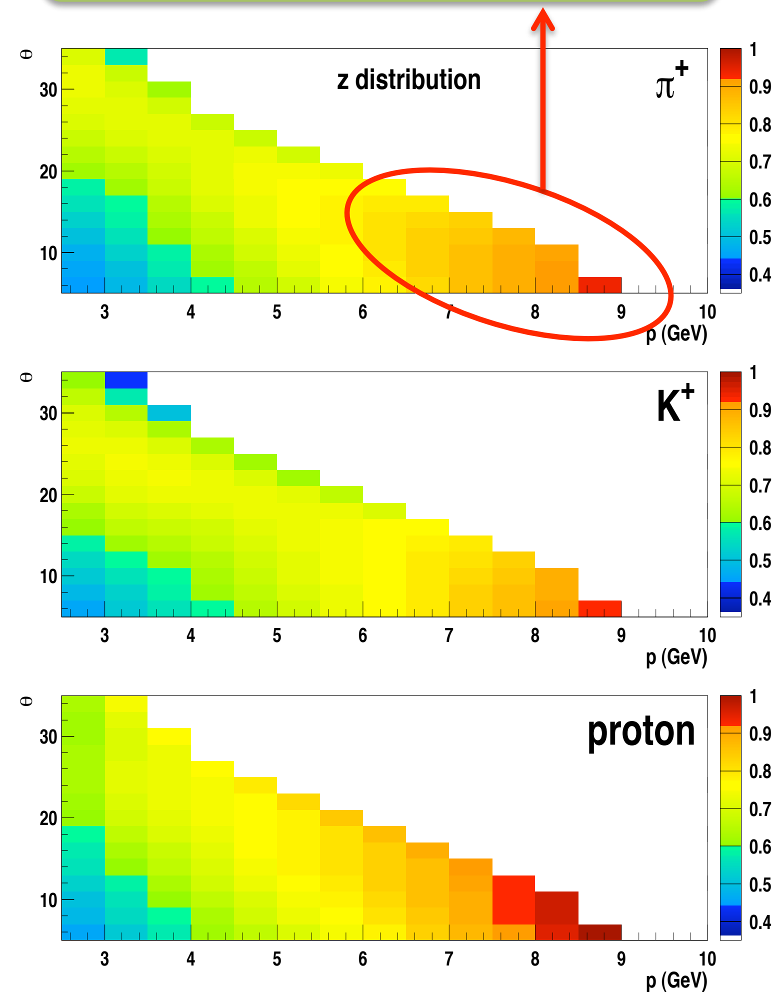



# SIDIS Kinematics @ CLAS12

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




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

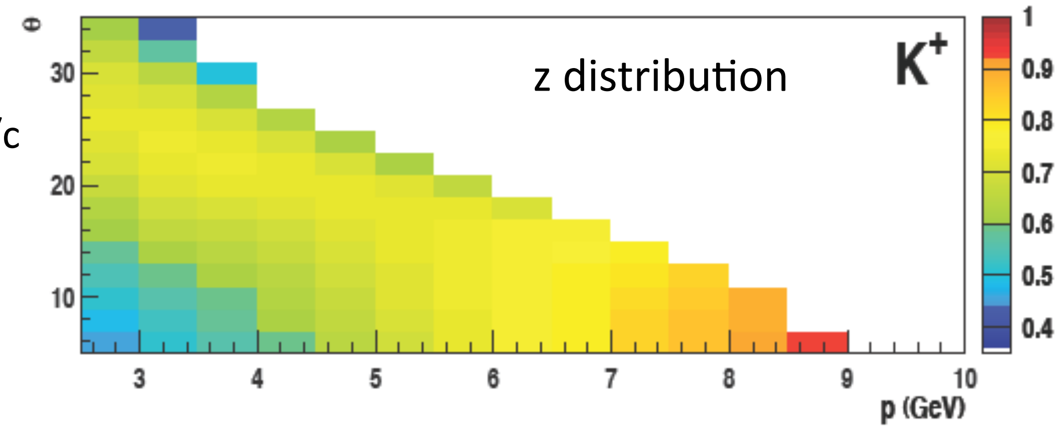


# RICH Requirements

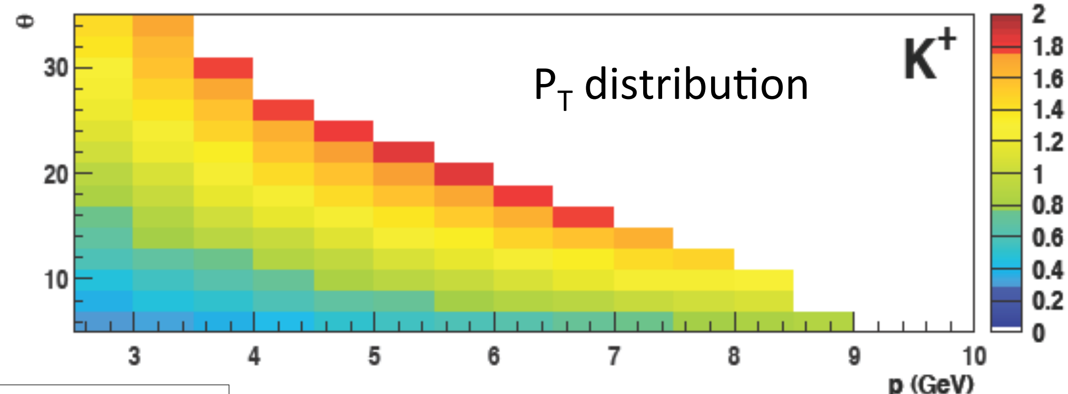
Full momentum coverage from 3 up to 8 GeV/c

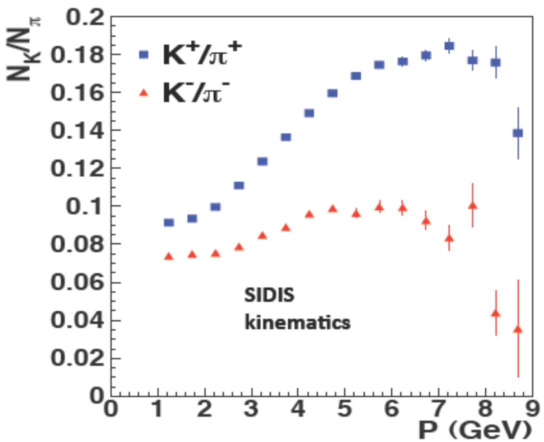
Pion rejection above 3 GeV/c

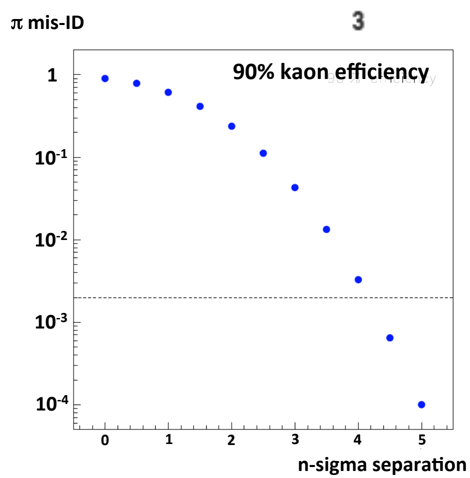
Proton rejection above 5 GeV/c




Angular coverage reaching above 20 and up to 25 degrees



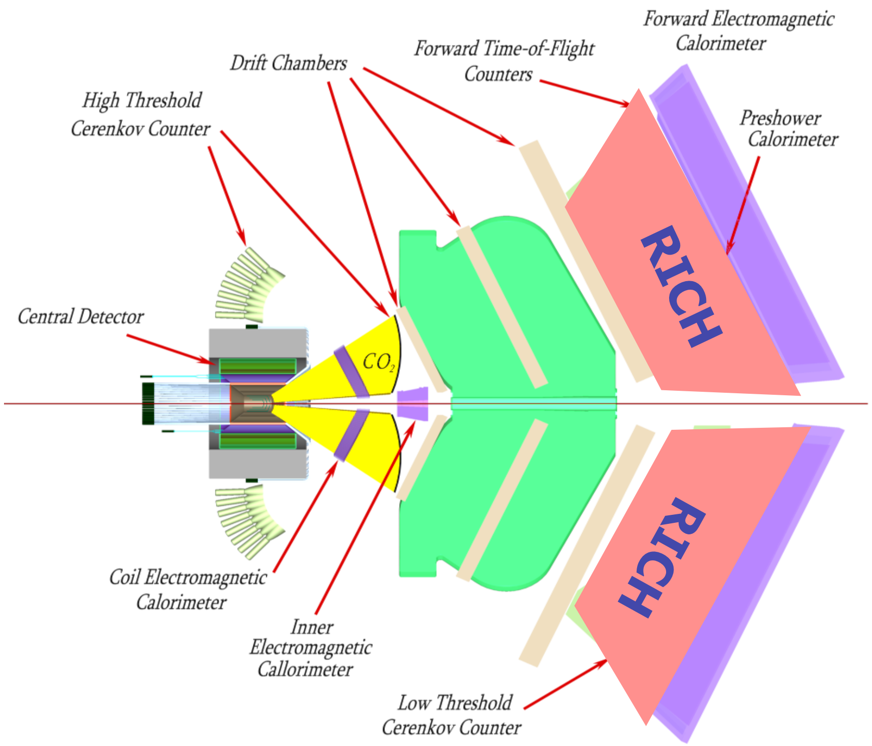

Contamination limited at the few % level

Pion rejection close to 500

Proton rejection close to 100

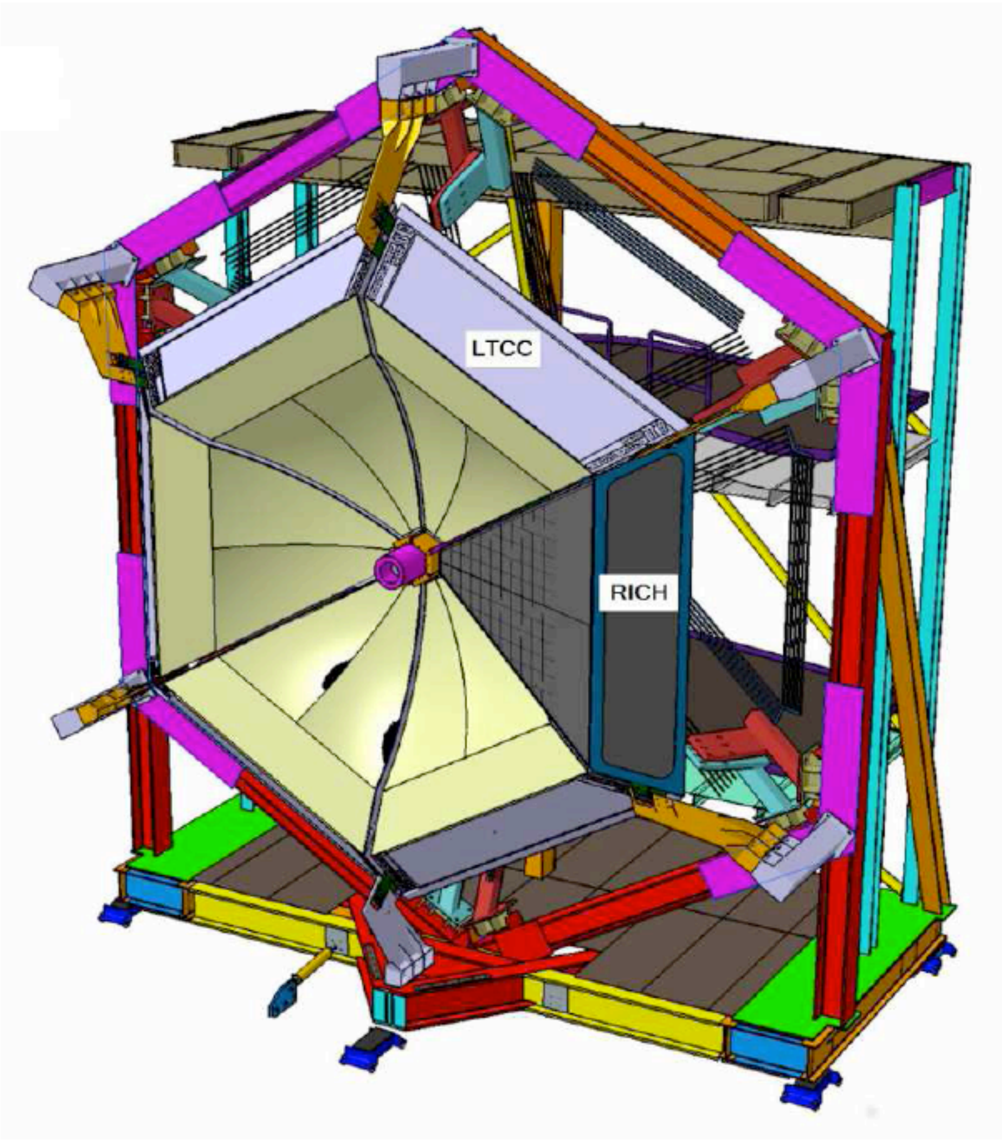
# The CLAS12 RICH

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



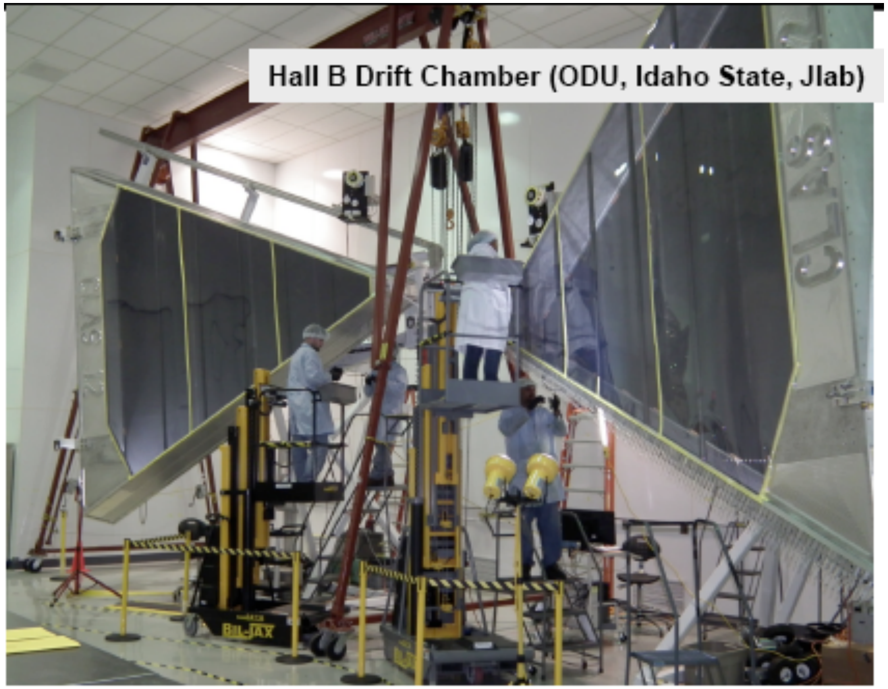

| INSTITUTIONS |
|---|
| INFN (Italy)<br>Bari, Ferrara, Genova, L.Frascati, Roma/ISS |
| Jefferson Lab (Newport News, USA) |
| Argonne National Lab (Argonne, USA) |
| Duquesne University (Pittsburgh, USA) |
| Glasgow University (Glasgow, UK) |
| J. Gutenberg Universitat Mainz (Mainz, Germany) |
| Kyungpook 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

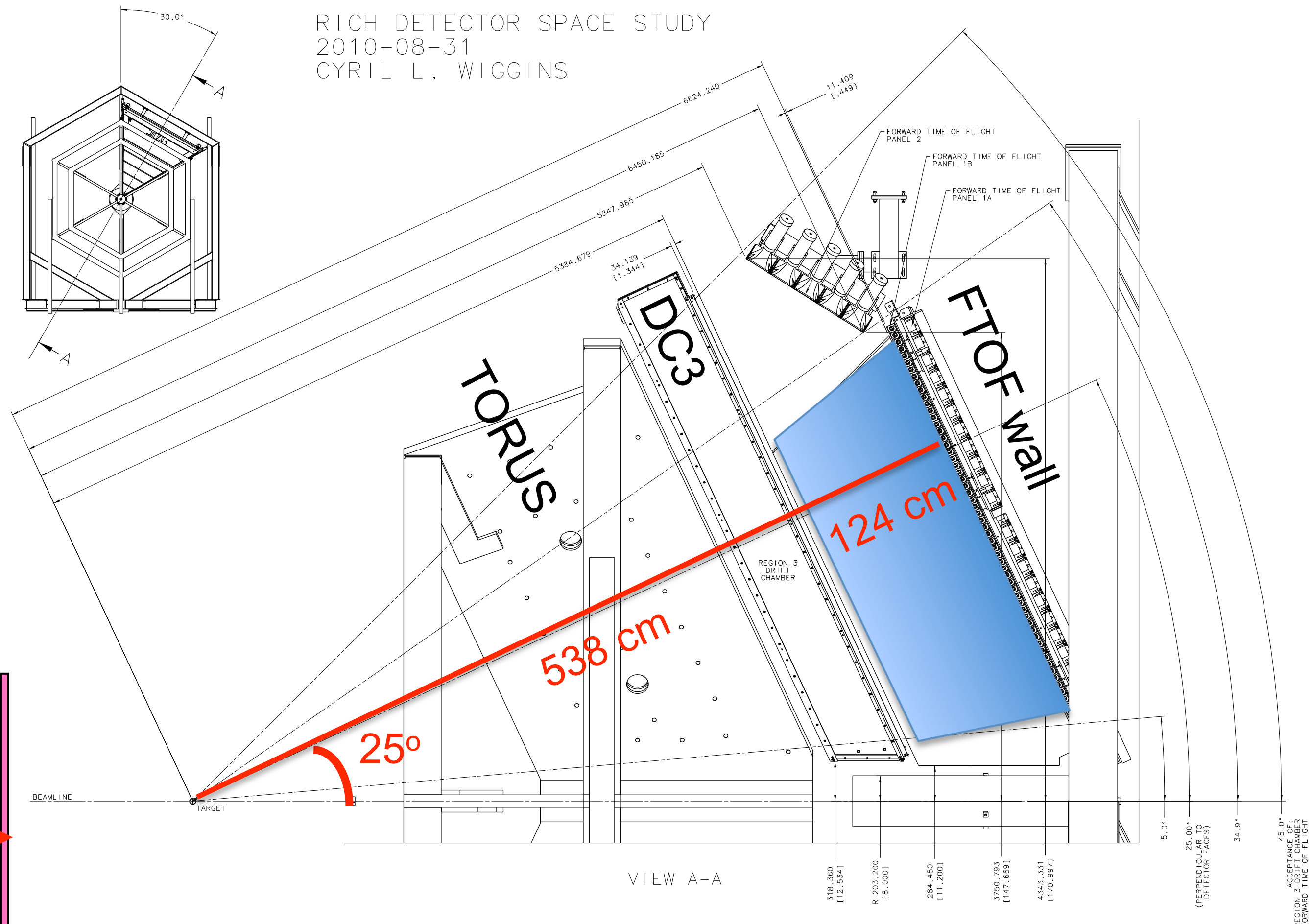
2nd++ sector useful for transverse target physics runs (left-right symmetry and statistics)



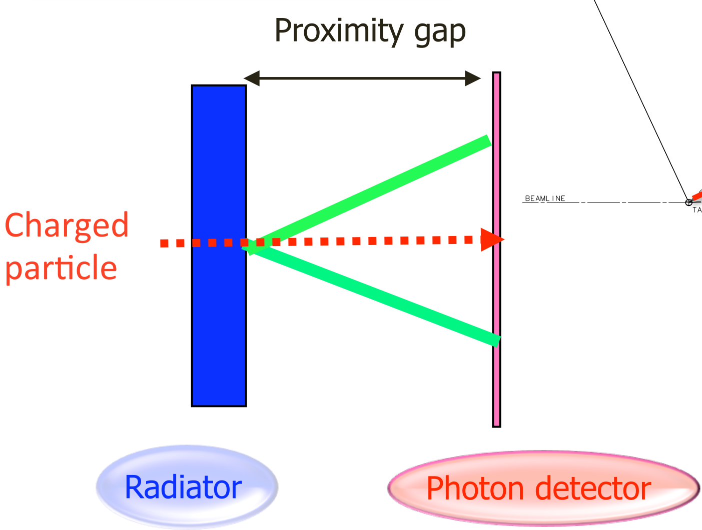
# CLAS12 Geometry Constraints

Base Numbers

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

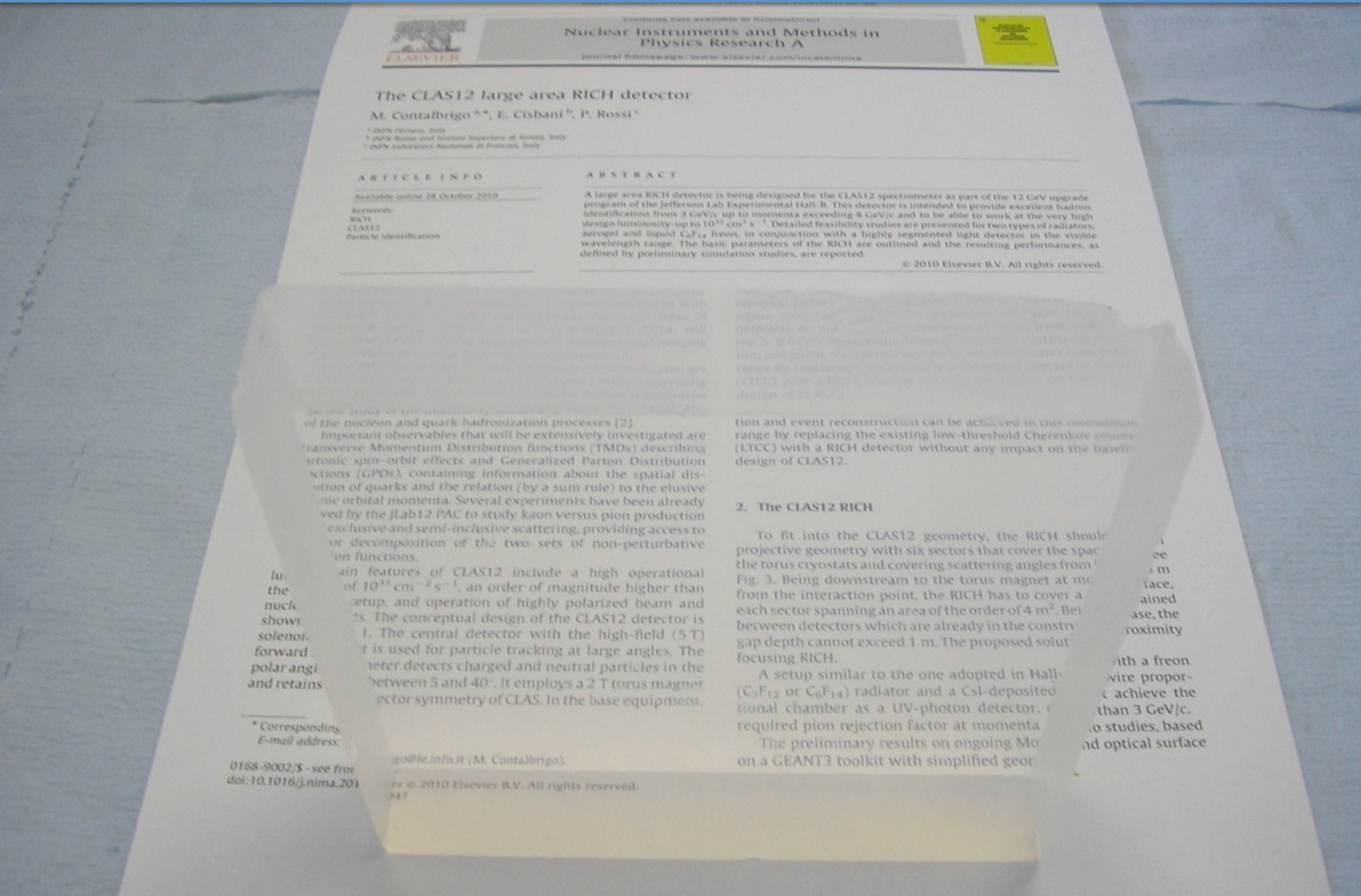



Proximity RICH



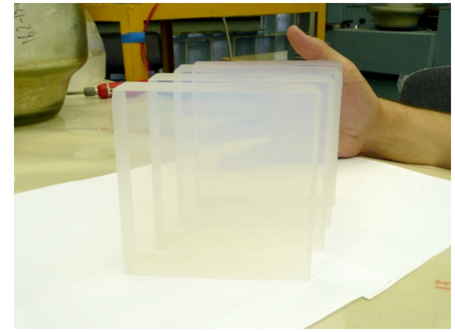
# Radiator

# Aerogel Radiator

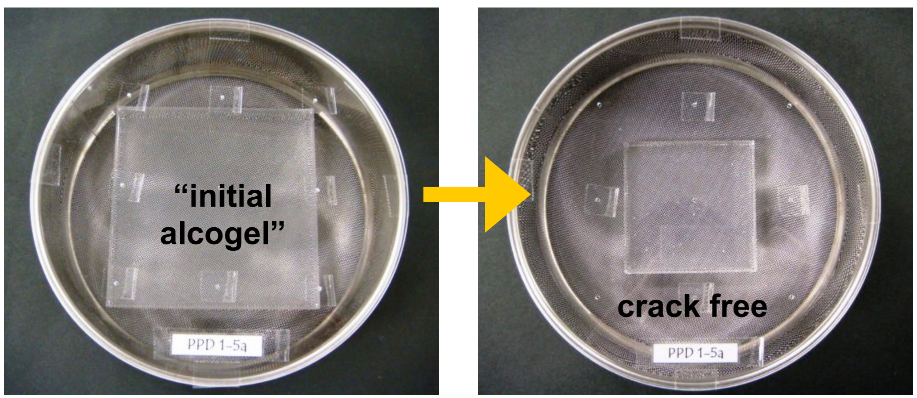


# Aerogel Transmission Length

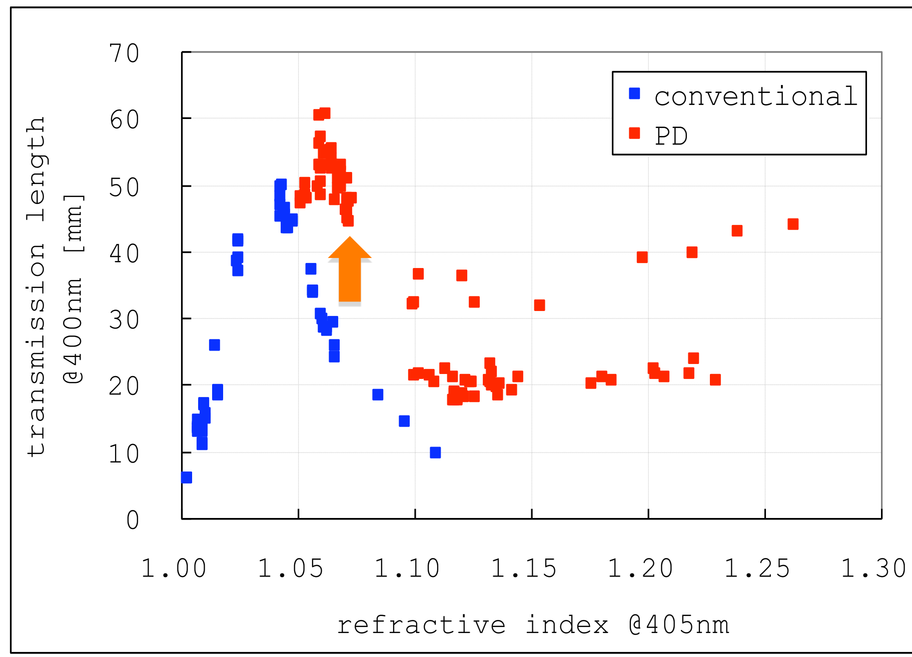
"Pinhole drying (PD)" method:
artificially shrinks alcogel to obtain high index
Transparency doubled for n>1.05 aerogel



M. Tabata @ RICH 2010




**pinhole drying process**



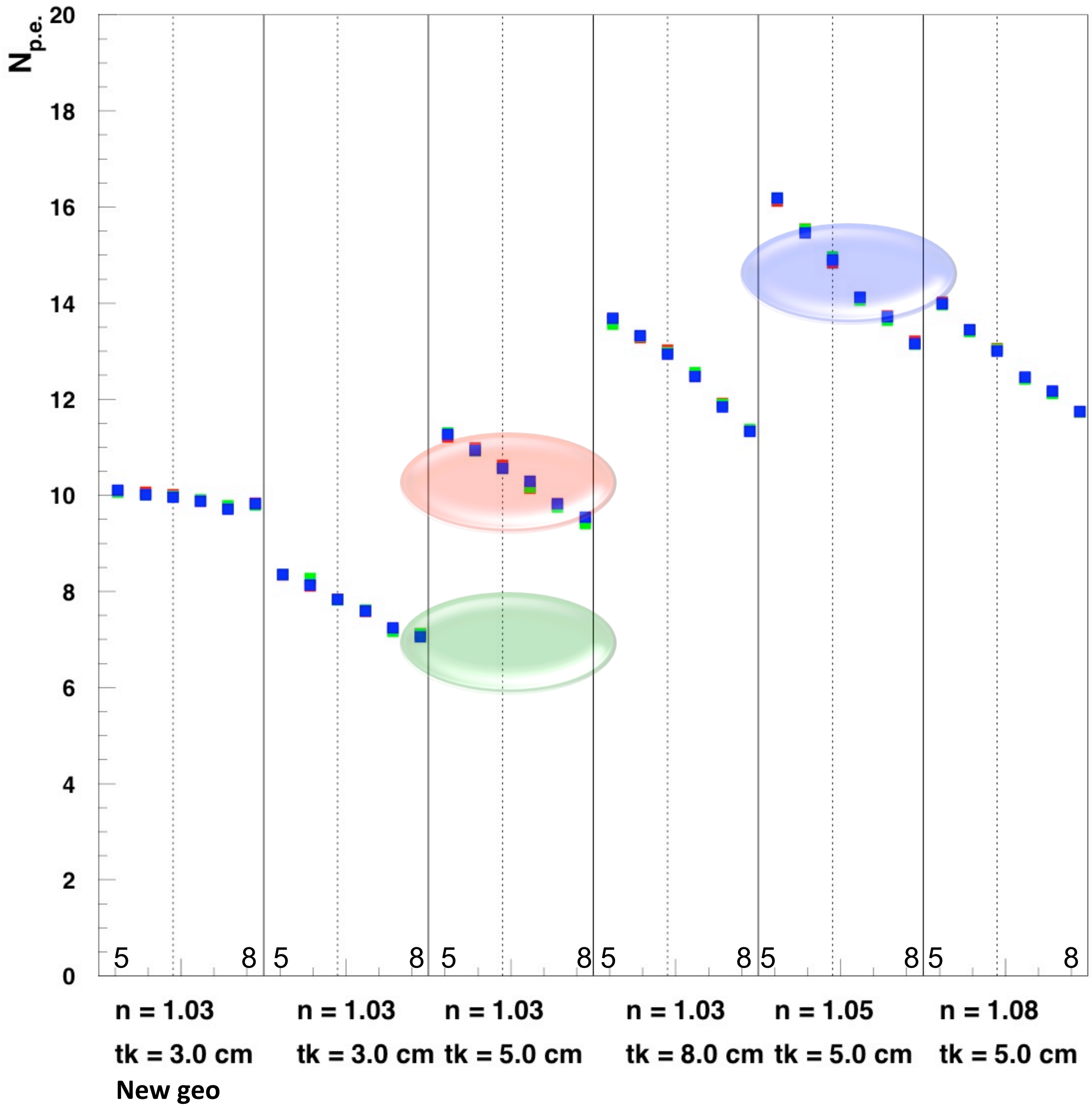

A.F. Danilyuk @ RICH 2010

| 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)

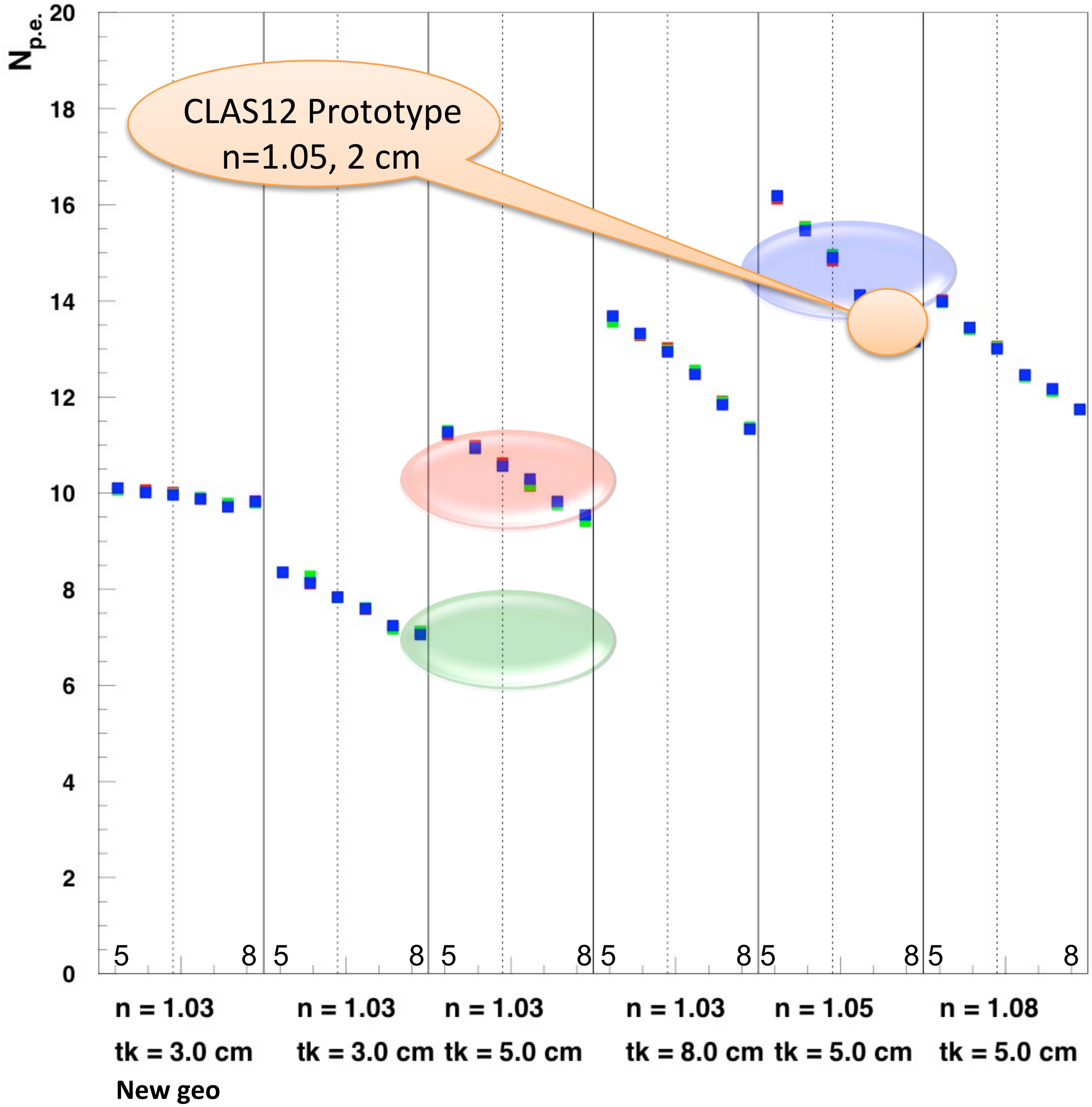



**BELLE II test-bench**
15 p.e. with aerogel of n ~ 1.05 refractive index and 4 cm thickness

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

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

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

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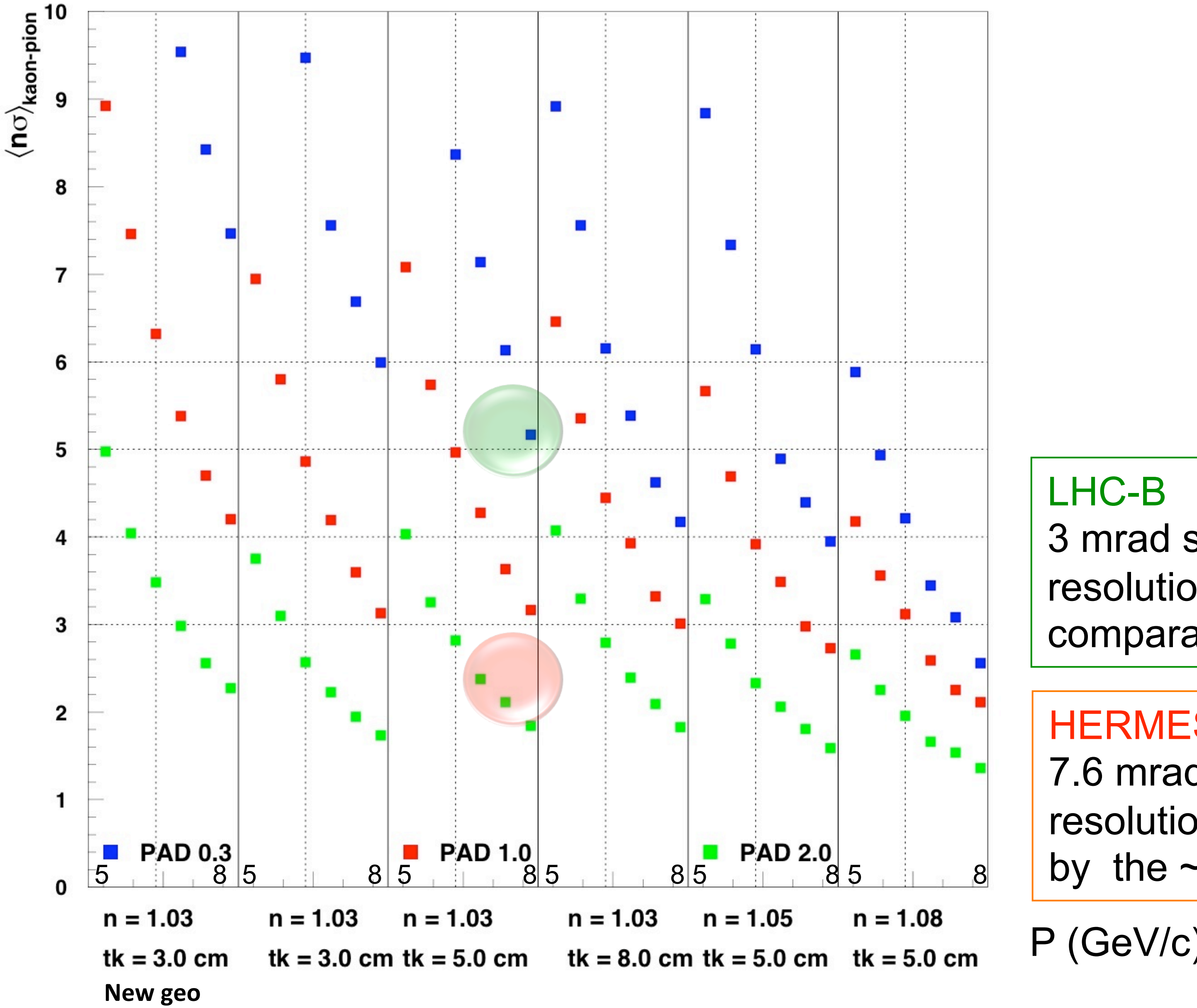
# Mean π/K Separation (5-8 GeV/c)




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

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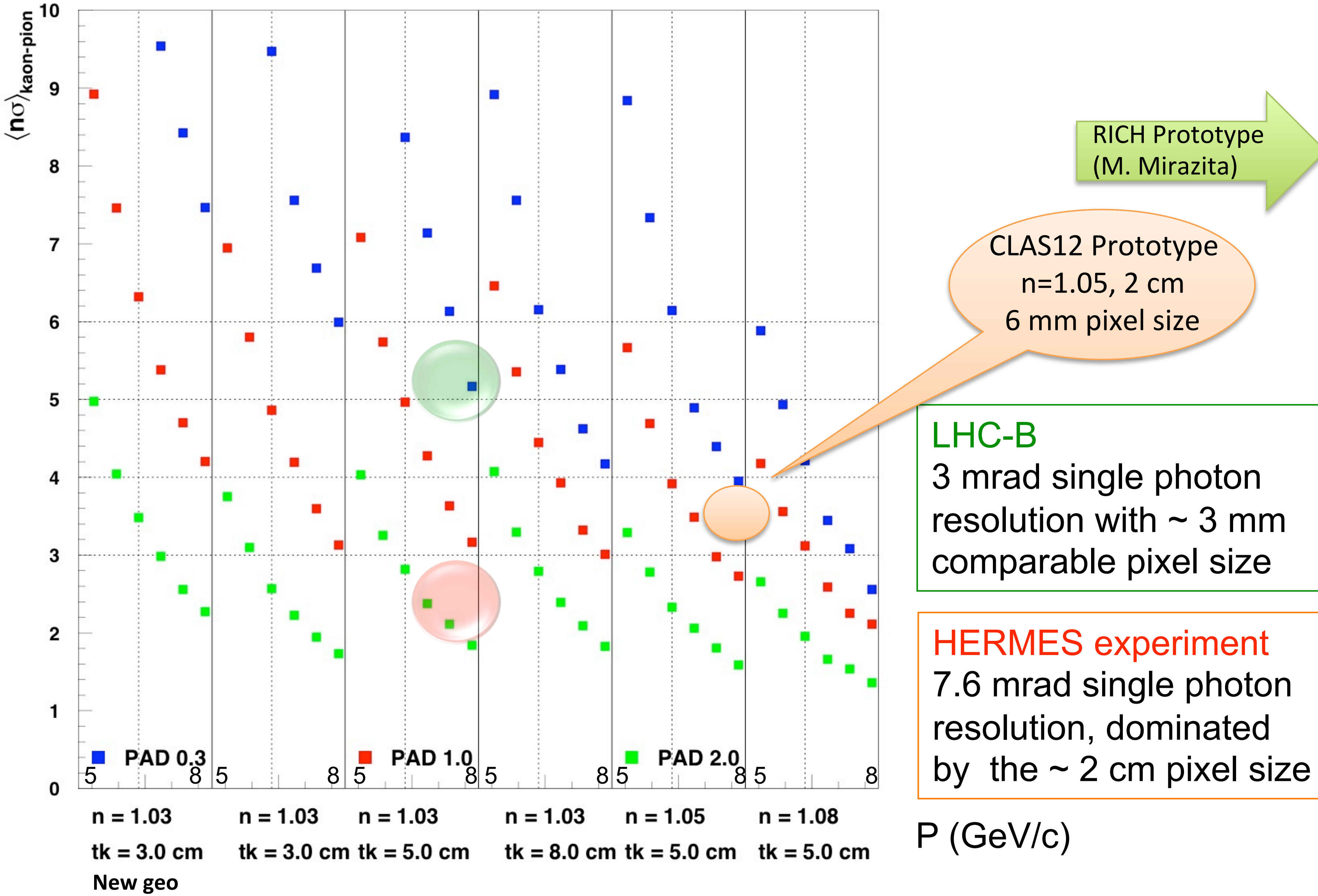



LHC-B
3 mrad single photon resolution with ~ 3 mm comparable pixel size

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

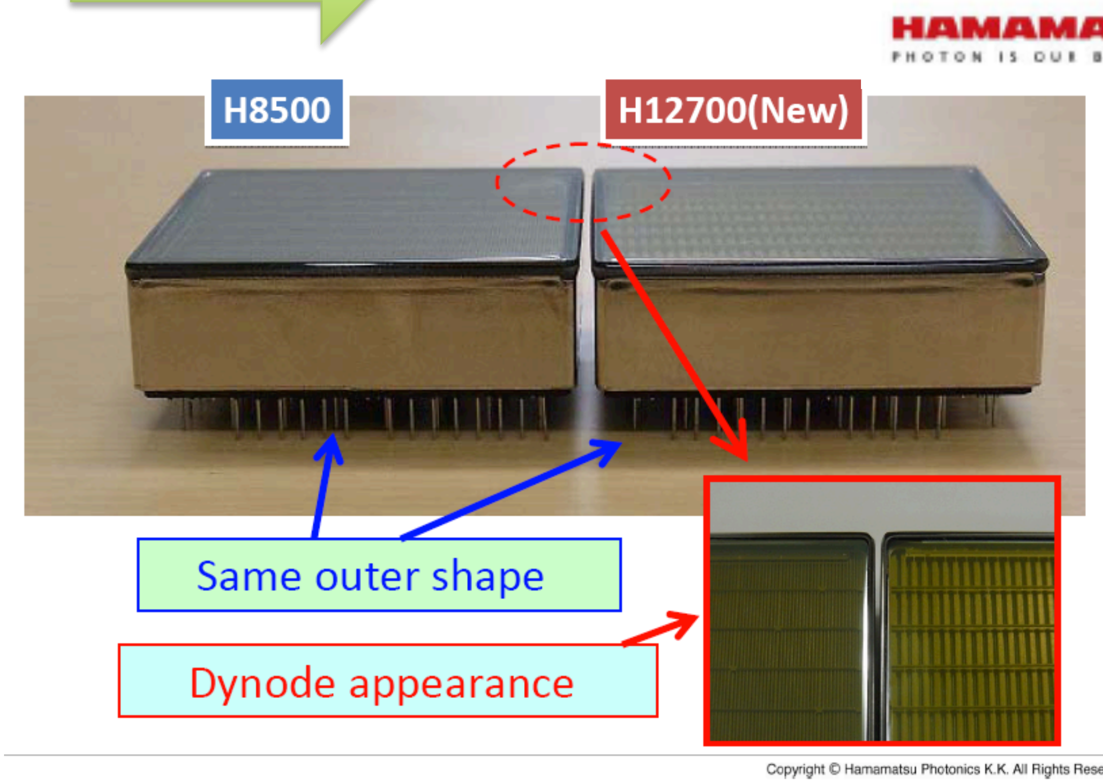
# PhotoDetector

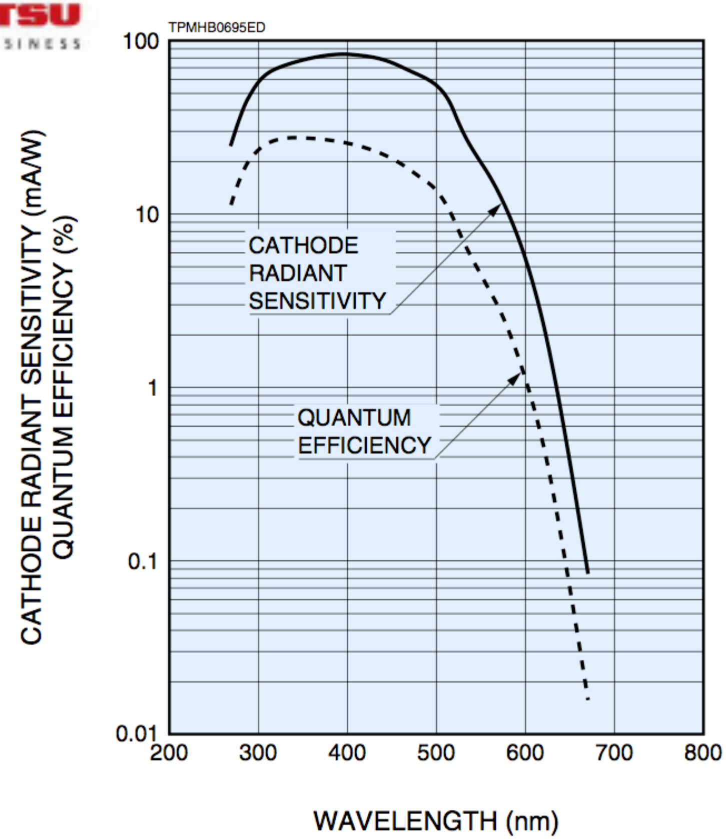
# Photon Detectors: MA-PMT

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

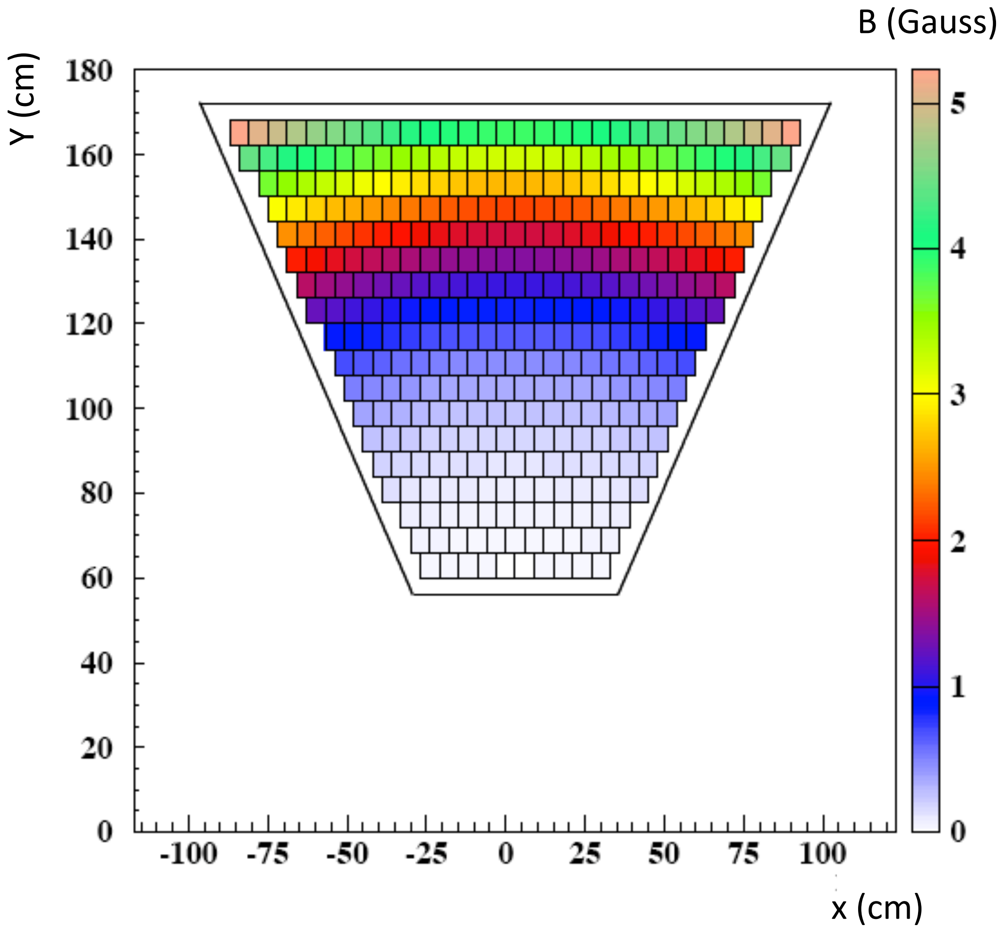
H8500 Tests
(M. Hoek)

- ✓ Mature and reliable technology
- ✓ Large Area (5x5 $cm^2$)
- ✓ High packing density (89 %)
- ✓ 64 6x6 $mm^2$ pixels cost effective device
- ✓ High sensitivity on visible towards UV light
- ✓ Fast response

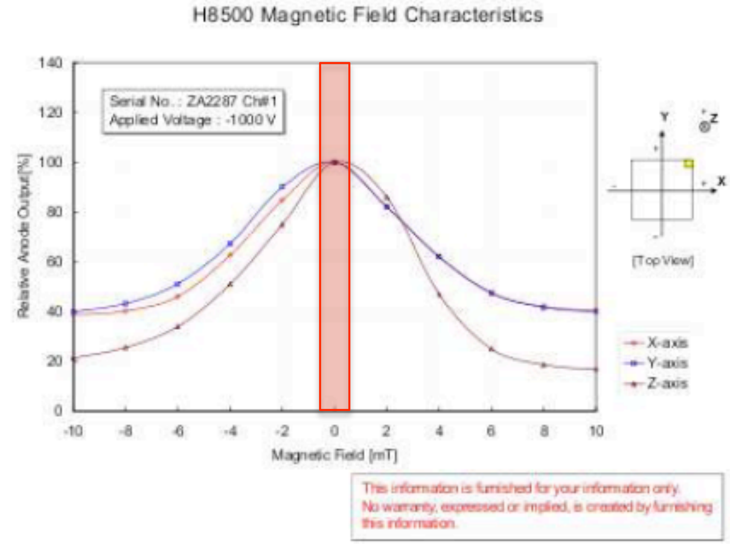


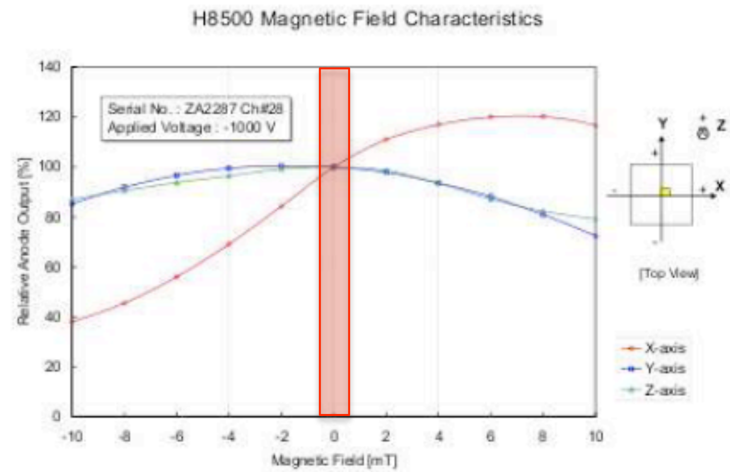



# Magnetic Field




HAMAMATSU




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

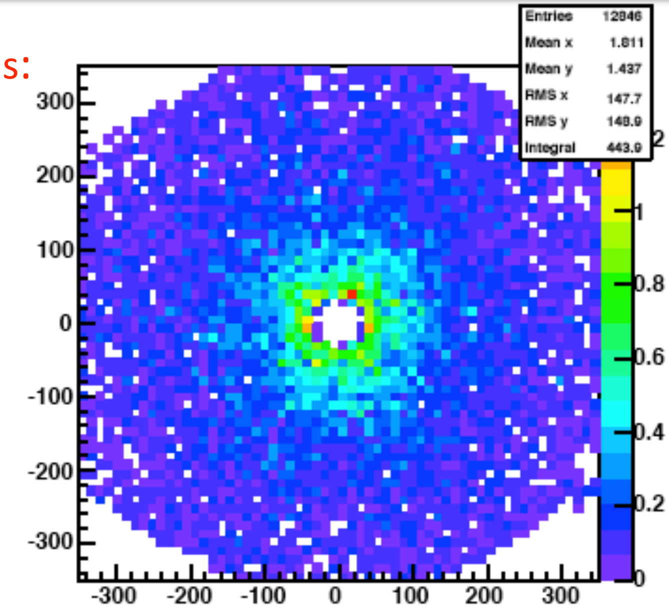
# Radiation Damage: Neutrons

Measured fluence @ Belle:
90/fb → 1-10 $10^9$ n/cm$^2$

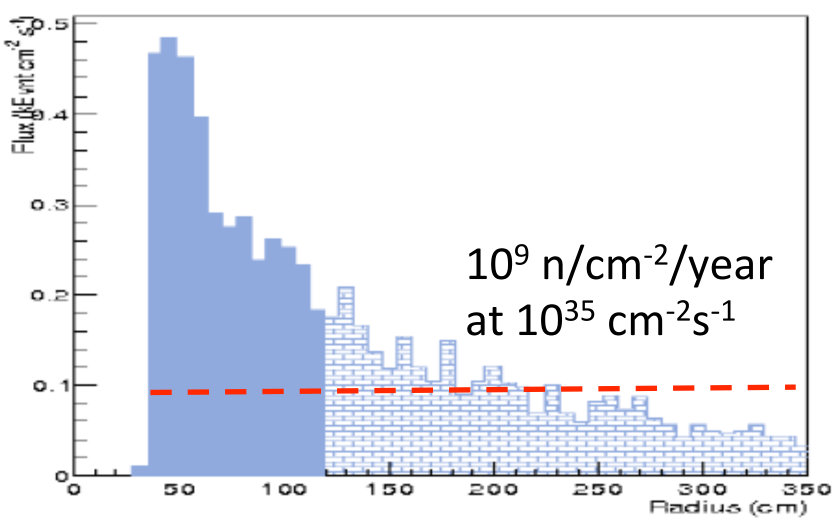
Expected fluence @ Belle-2:
50/ab → 2-20 $10^{11}$ n/cm$^2$

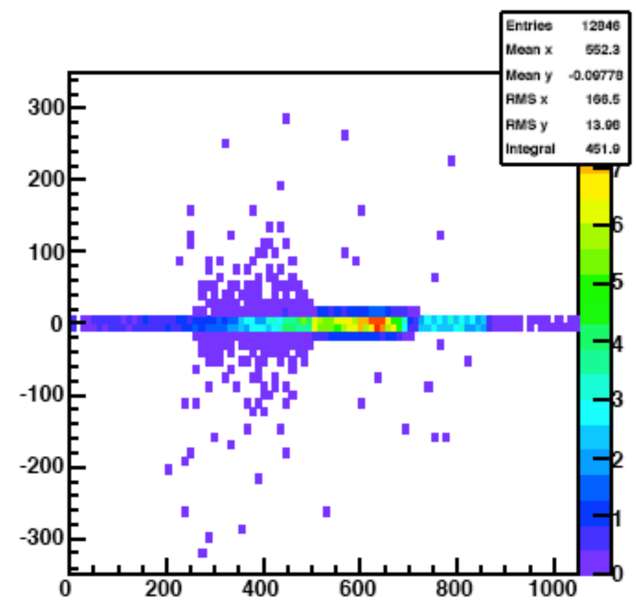
Expected fluence @ LHCB-2:
1 year → 6 $10^{11}$ n/cm$^2$

Neutrons:



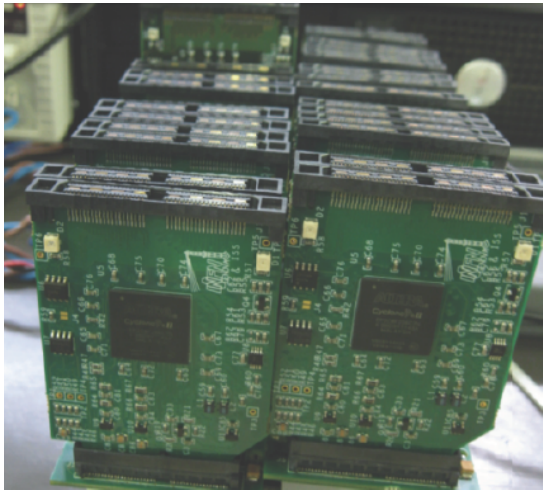

Neutrons:



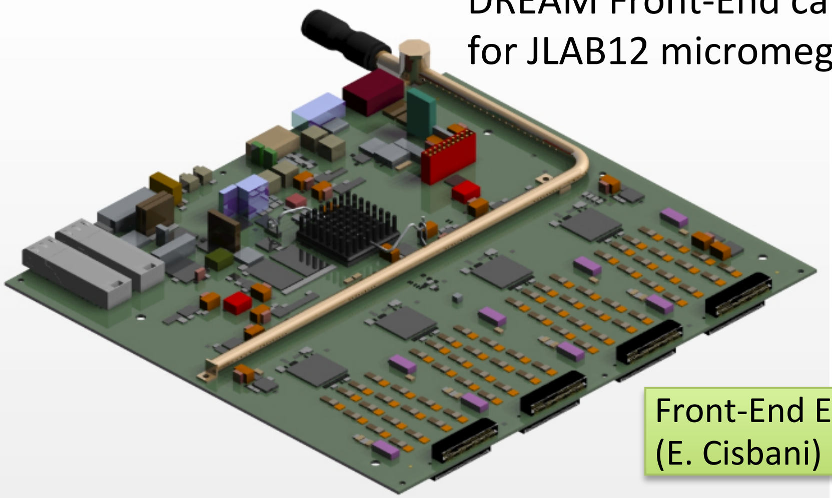
# MA-PMTs Readout

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



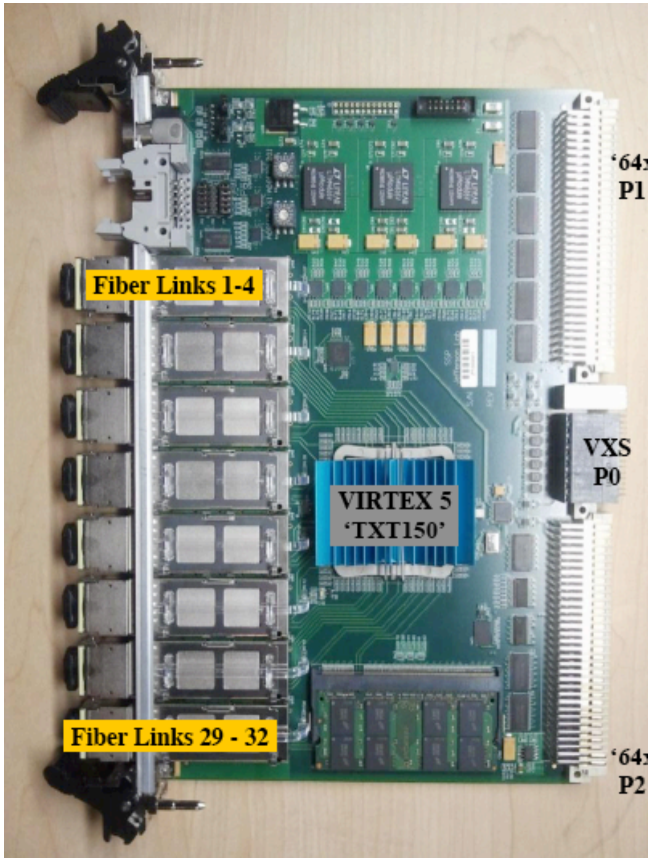
Basic components with already existing designs and prototypes

DREAM Front-End card developed for JLAB12 micromegas readout



Front-End Electronics
(E. Cisbani)

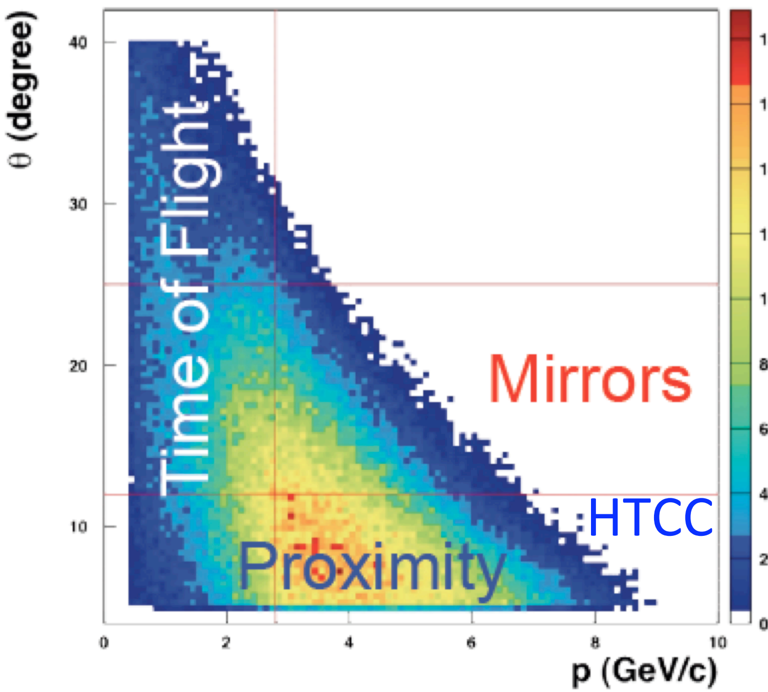
VME DAQ Optics FPGA module Developed for GLUEX and JLAB12

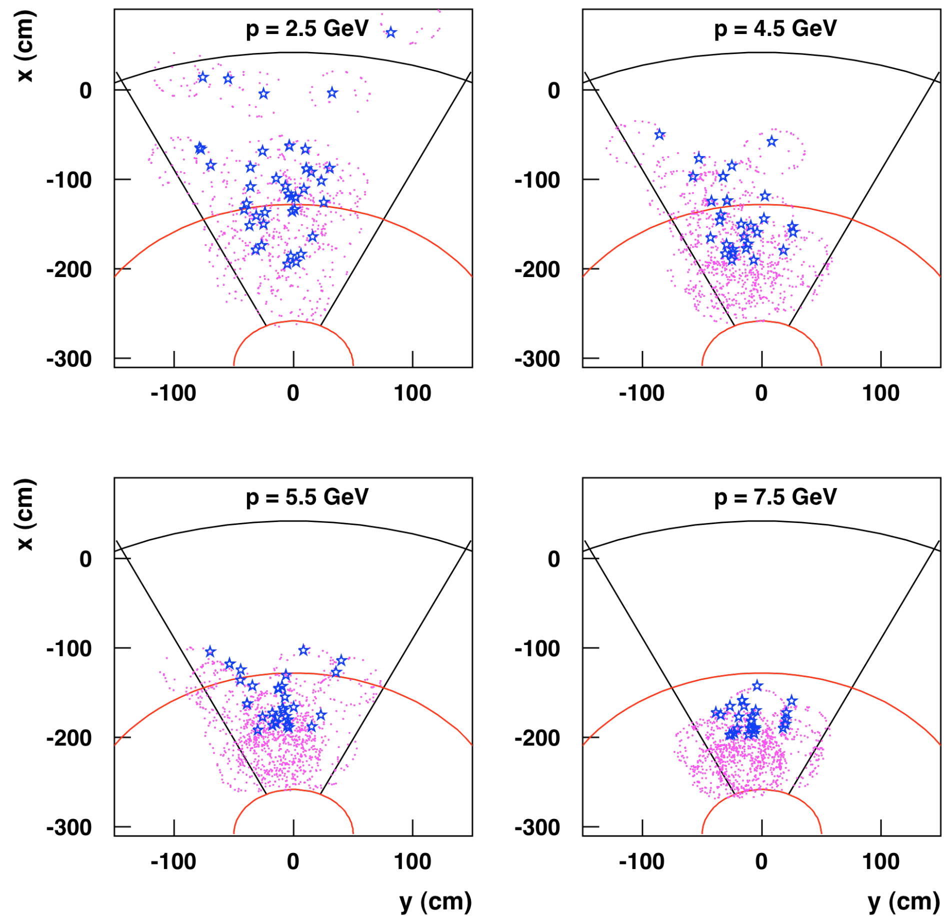



DAQ and Trigger
(C. Cuevas)

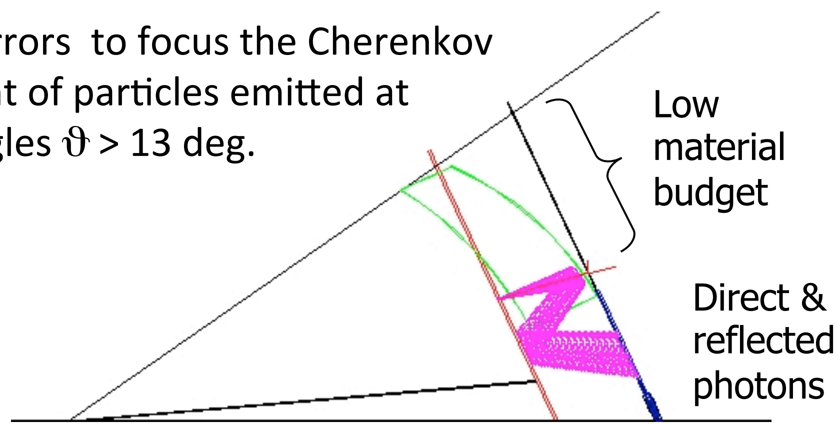
# The Mirror System

# The Mirror System




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

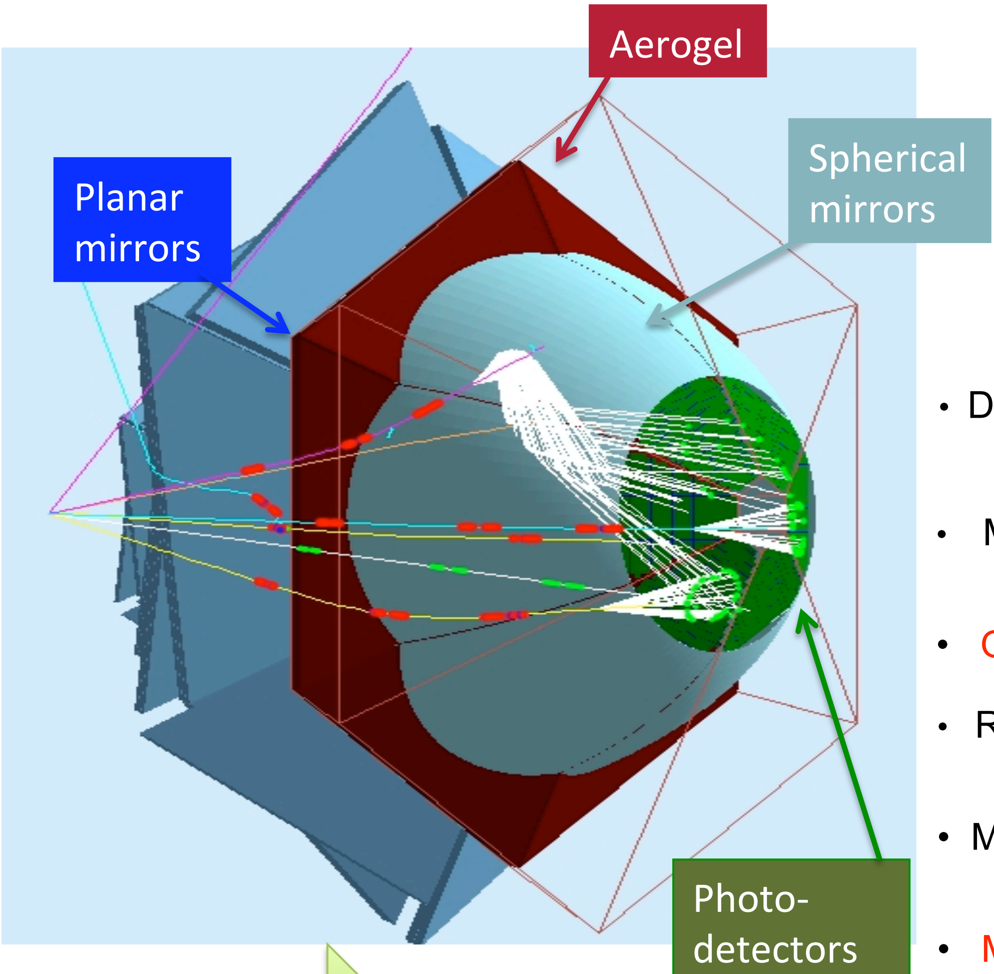


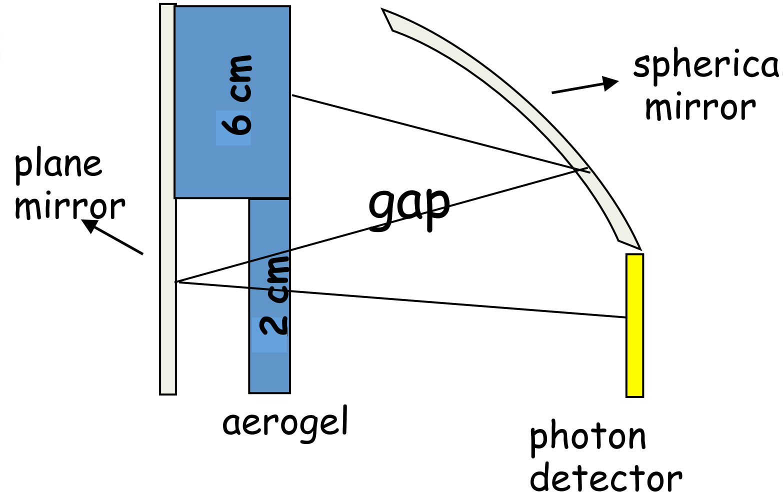

**Goals:**

- instrument only forward region
- reduce active area (~1 $m^2$/sector)
- minimize interference with TOF system

# The Mirror System

## Proximity Focusing RICH + Mirrors




- 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)

Integration in CLAS12 (M. Contalbrigo)

# Mirror Technology

Metalized Carbon Fiber substrate
for spherical mirror

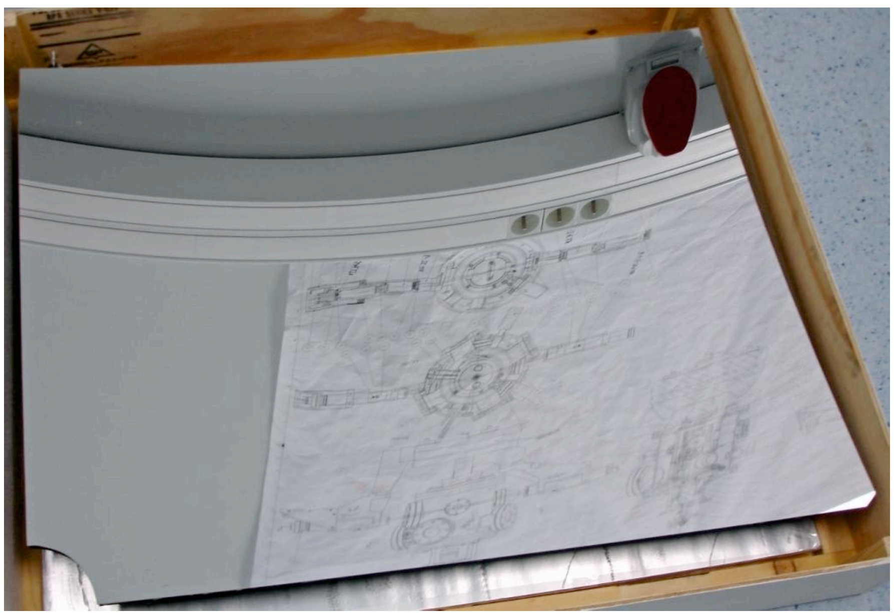
Self-supporting structure with
minimal material budget
(applications in physics experiments)

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)

standard technologies already in use and commercially available



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-$N_2$ gap.
An even smaller yield is expected with dry air or $CO_2$

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**