

RICH PROJECT OVERVIEW

Contalbrigo Marco
INFN Ferrara

Rich Project Review, 5th September 2013

The CLAS12 Spectrometer

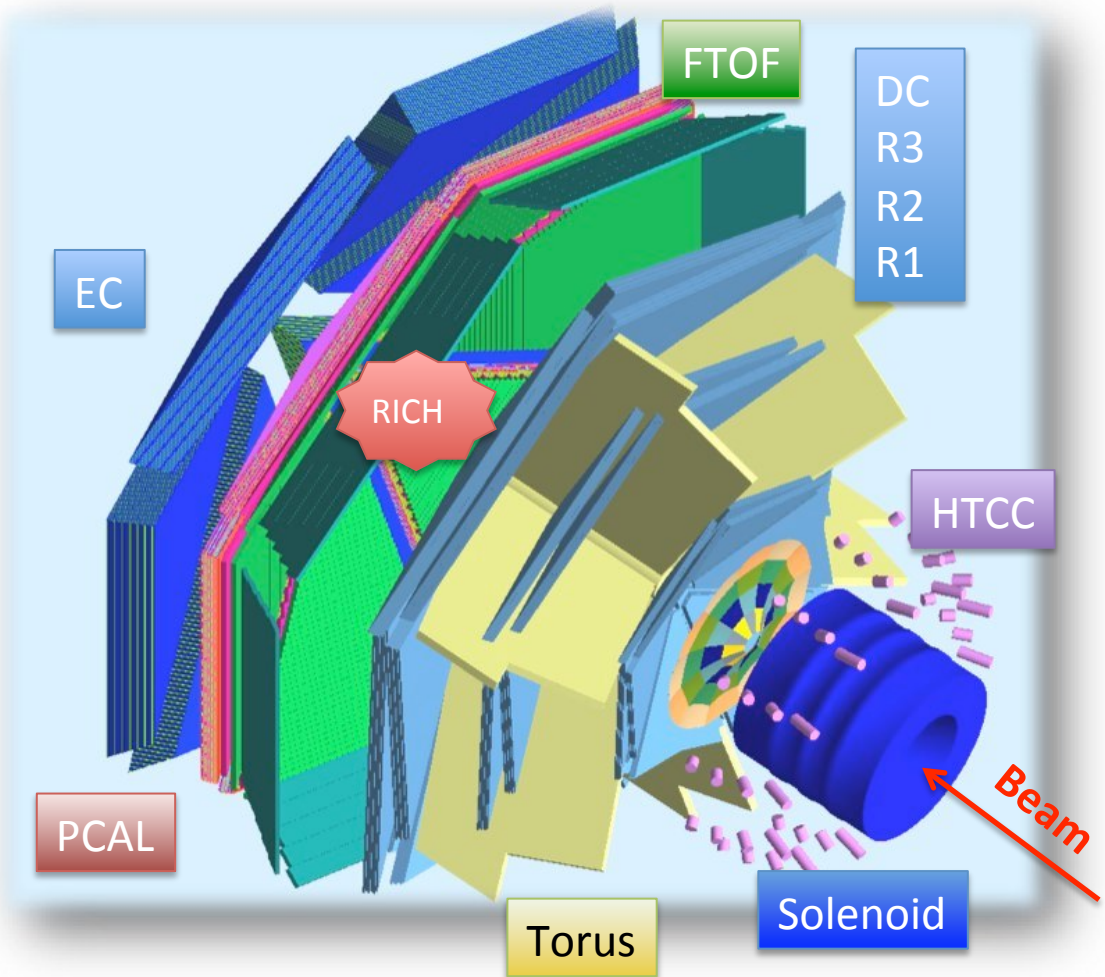
Luminosity up to $10^{35} \text{ cm}^{-2} \text{ s}^{-1}$

Highly polarized electron beam

H and D polarized targets

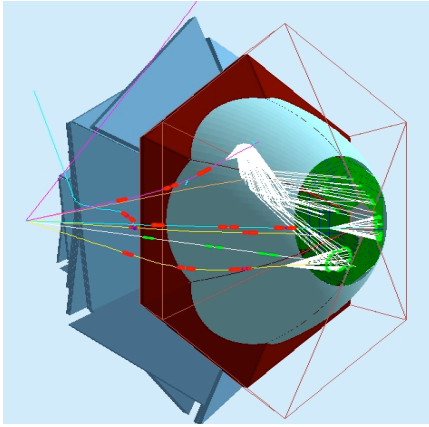
Broad kinematic range coverage
(current to target fragmentation)

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



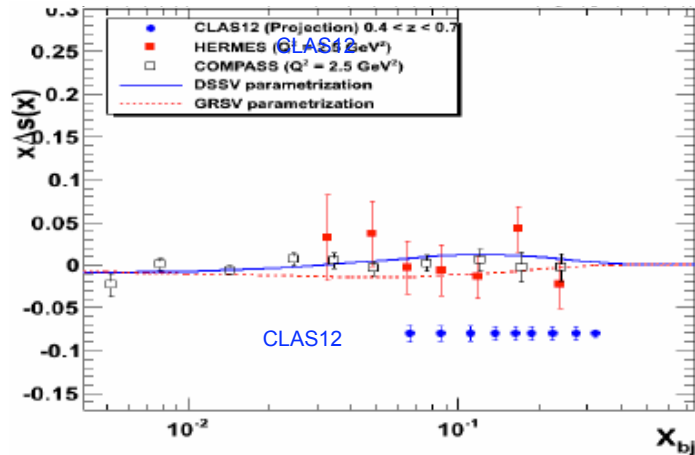
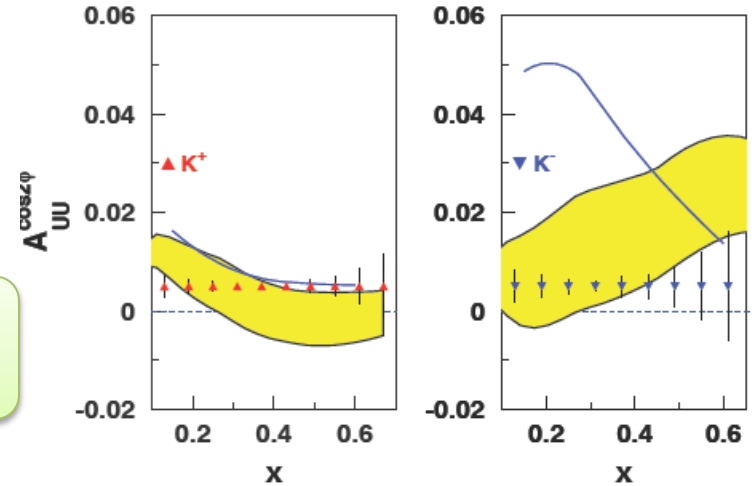
PAC30 report (2006): Measuring the kaon asymmetries is likely to be as important as pions The present capabilities of the present CLAS12 design are weak in this respect and should be strengthened.

Kaon SIDIS Program @ CLAS12



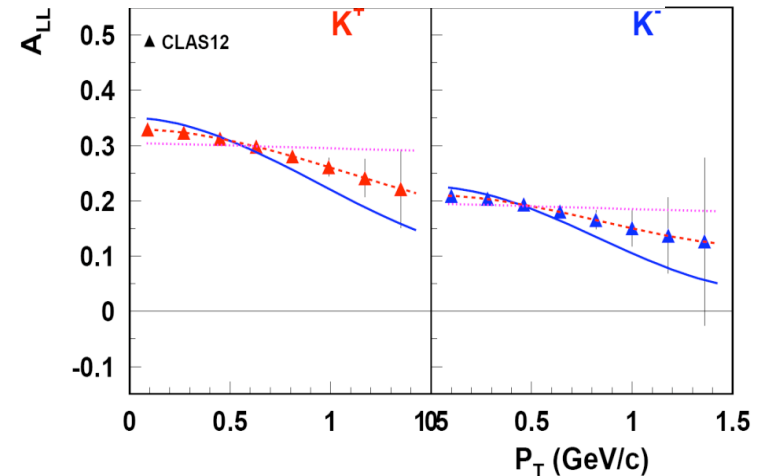
RICH detector for flavor separation of quark spin-orbit correlations in nucleon structure and quark fragmentation

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



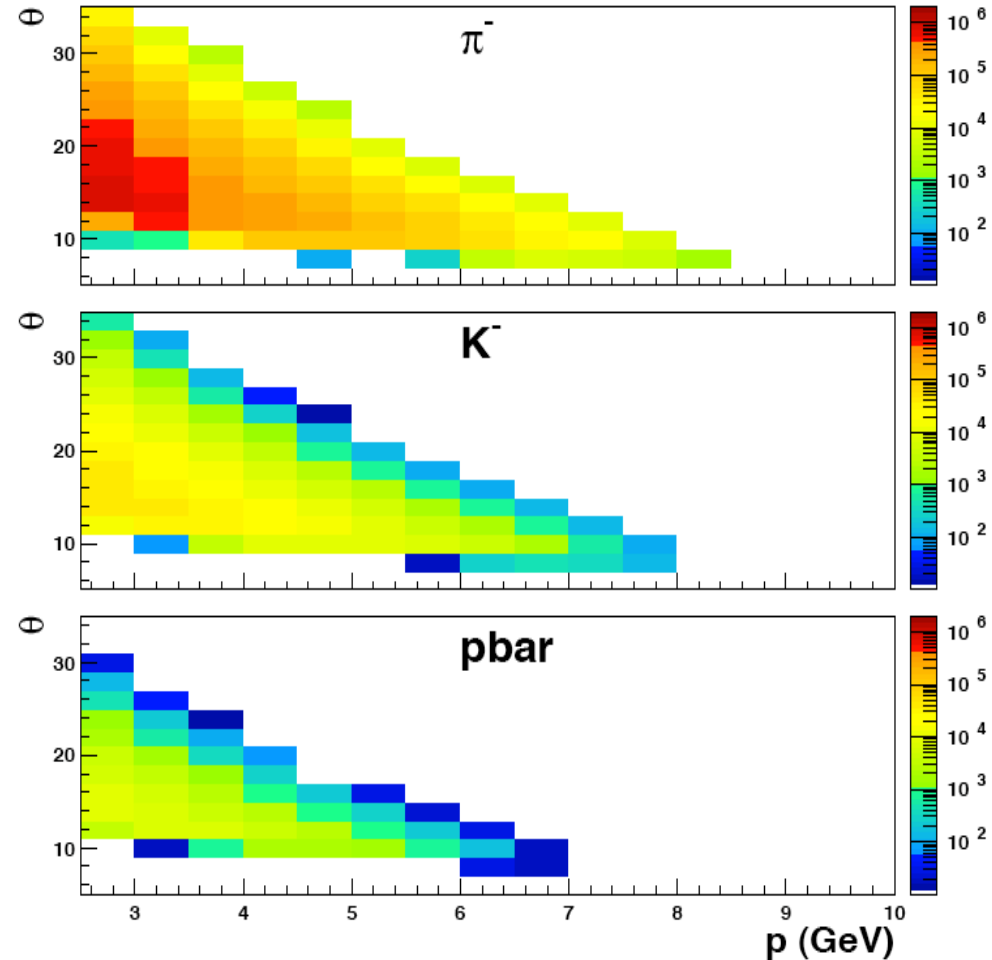
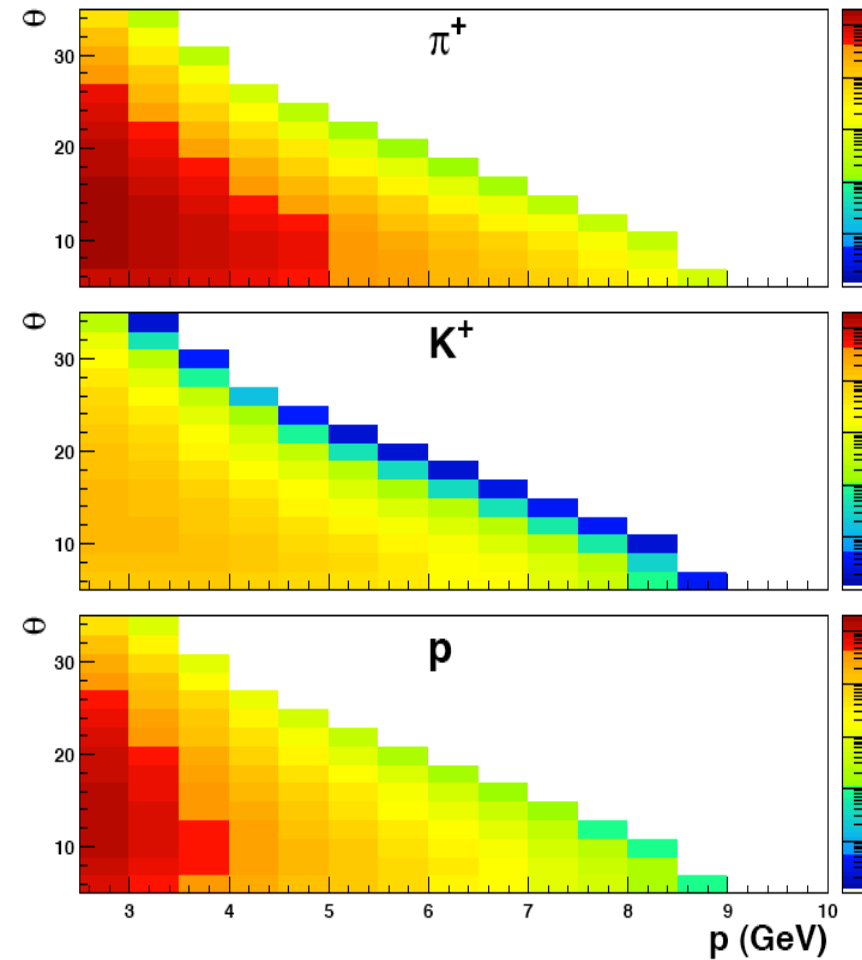
E12-09-07:

Studies of partonic distributions using semi-inclusive production of Kaons

SIDIS Kinematics @ CLAS12

Out-bending particles

In-bending particles



Baseline PID @ CLAS12

HTCC (electron ID):

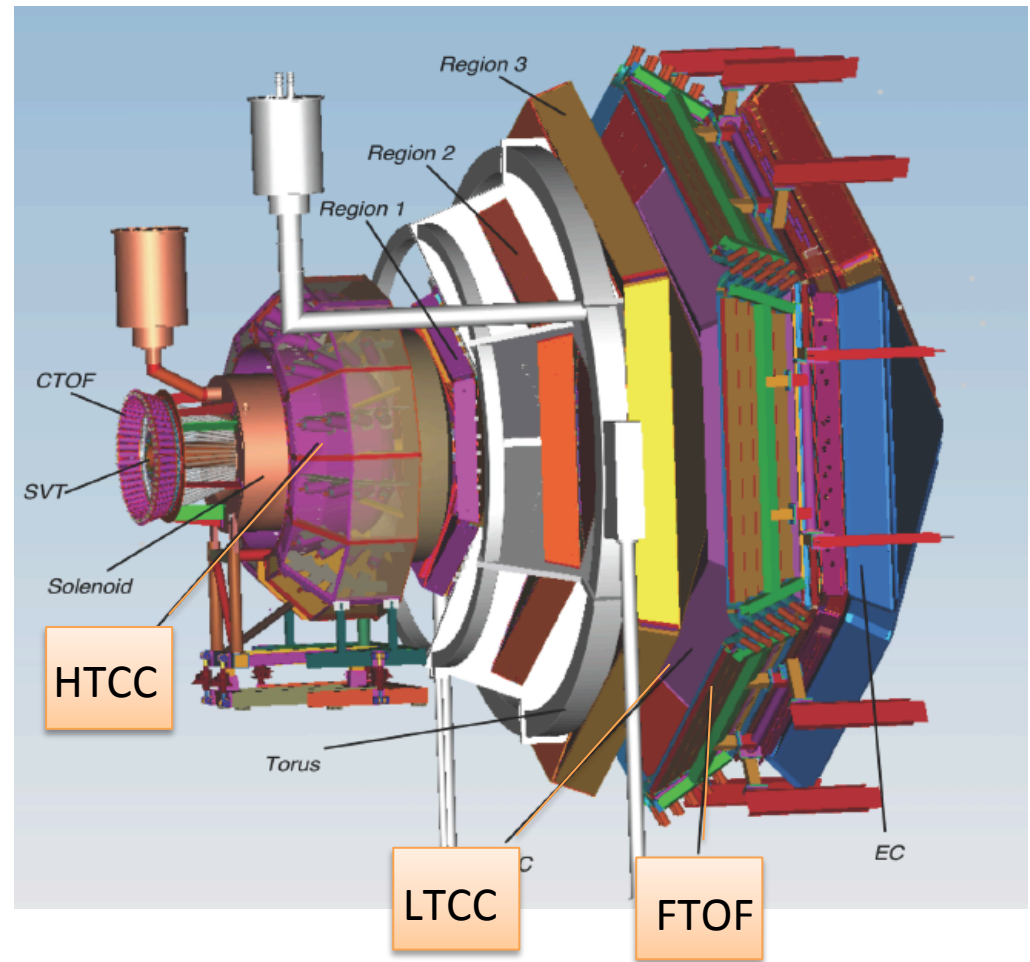
High Threshold Cherenkov Counter

FTOF (< 3 GeV/c hadron ID):

Forward Time-of-Flight system

LTCC (pion ID):

Low Threshold Cherenkov Counter



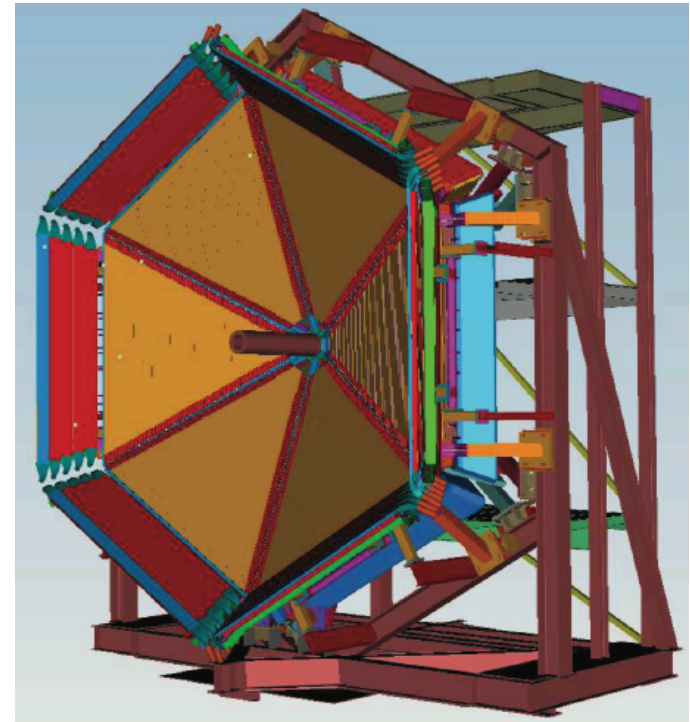
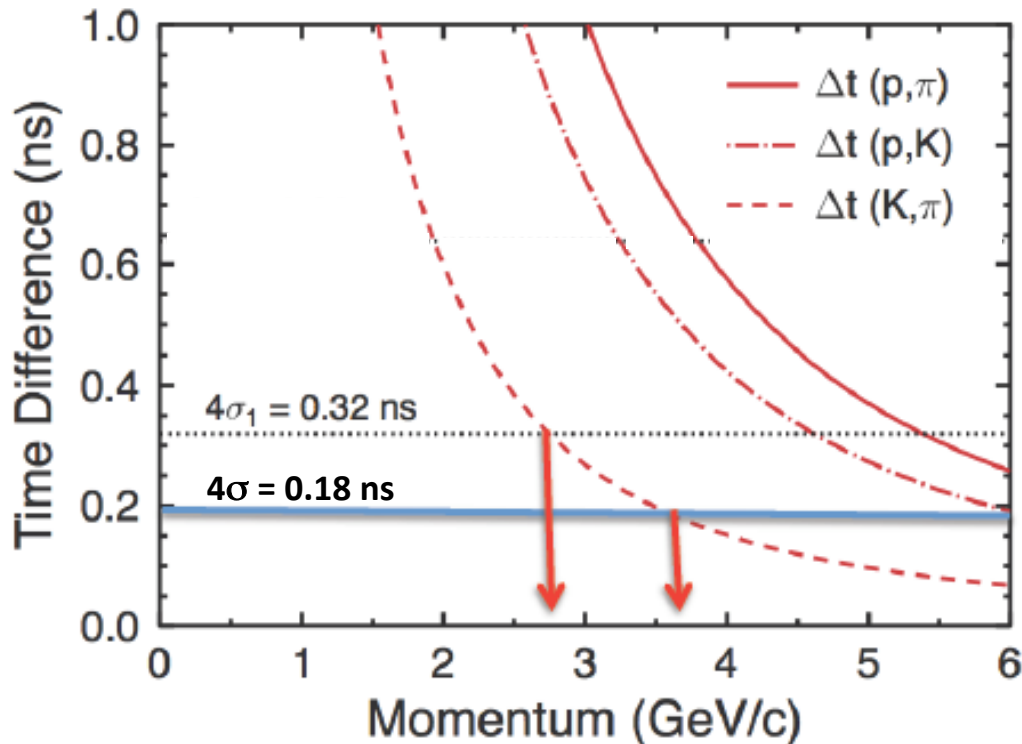
FTOF @ CLAS12

Two scintillators panels:
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



Time separation at 650 cm from IP:

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

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

for 90 % kaon efficiency

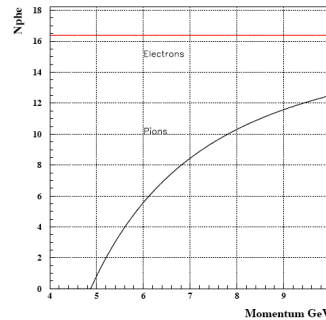
HTCC @ CLAS12

New detector for electrons ID:

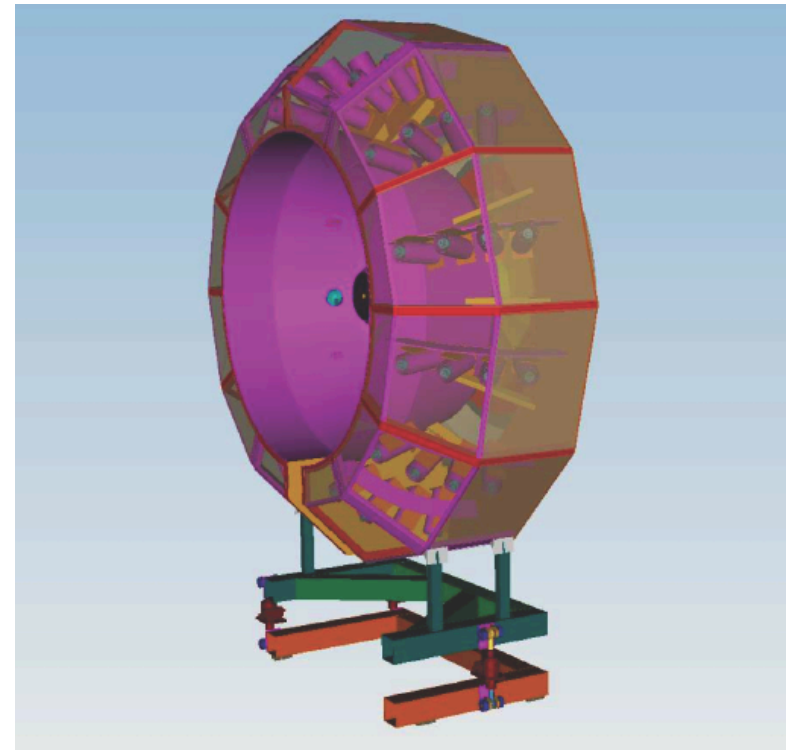
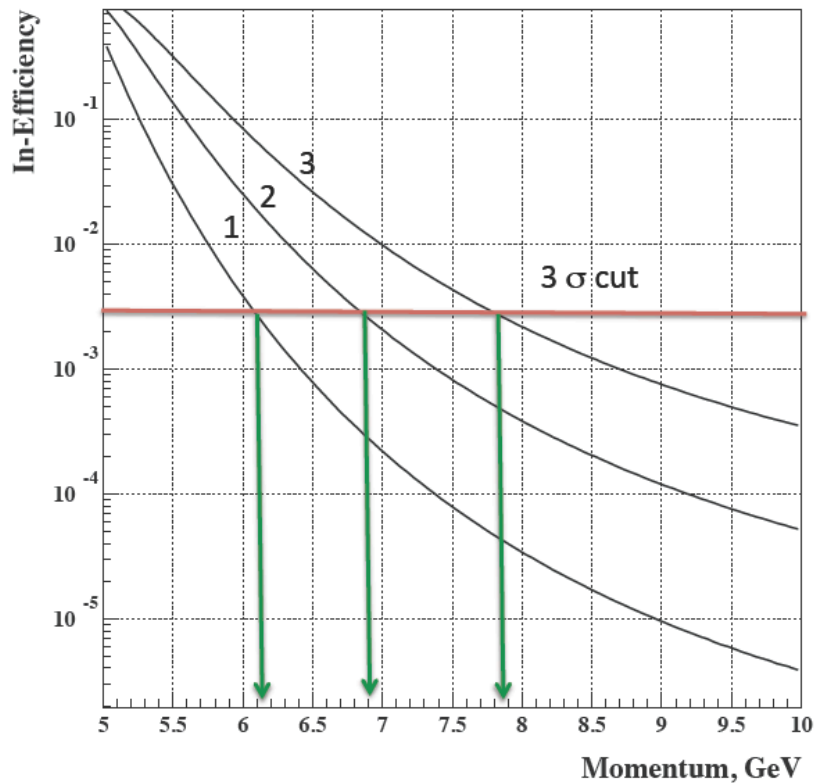
CO₂ radiator

48 5" quartz window PMTs

Hermetic with uniform response



Expected number of photoelectrons ~ 16



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

100 % below 5 GeV/c (Cherenkov threshold)

\sim % level around 6 GeV/c

\sim few per mil above 7 GeV/c

LTCC @ CLAS12

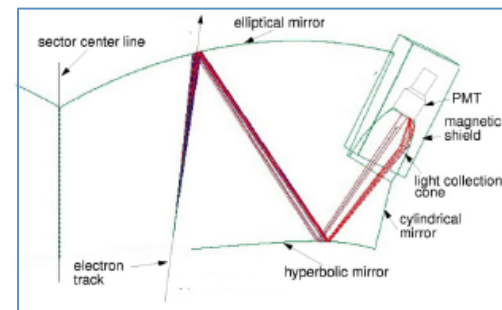
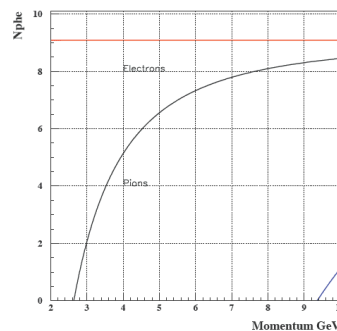
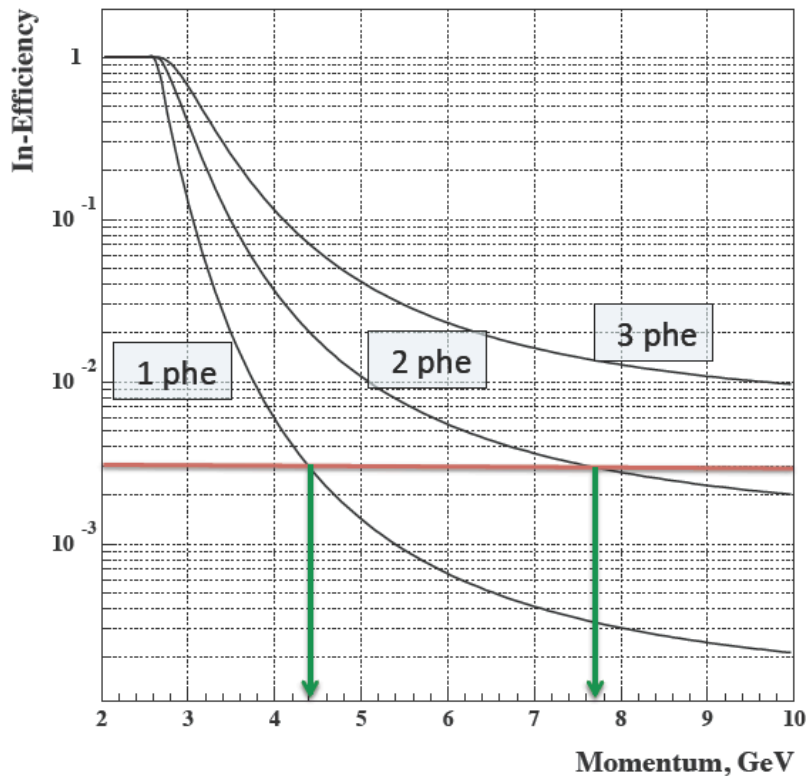
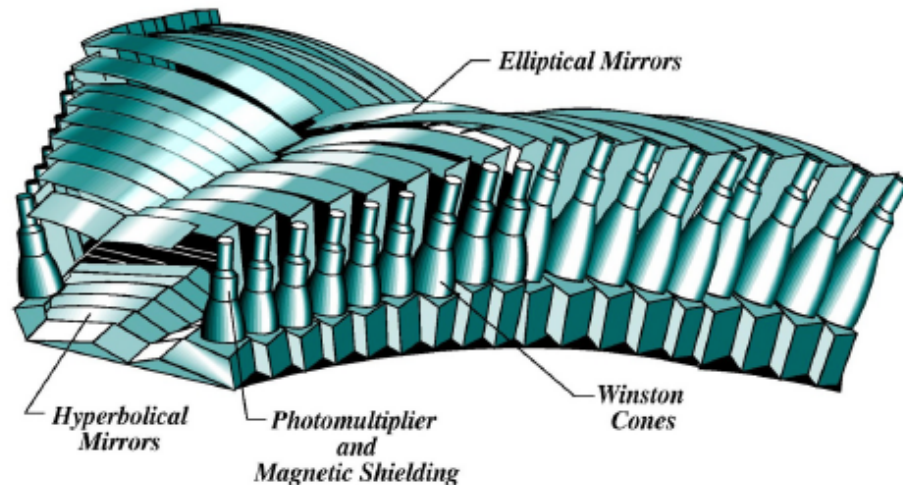
Derived from CLAS for pion ID:

C_4F_{10} radiator

Complicated design with irregular response

Limited ϕ acceptance

Expected number of photoelectrons ~ 9



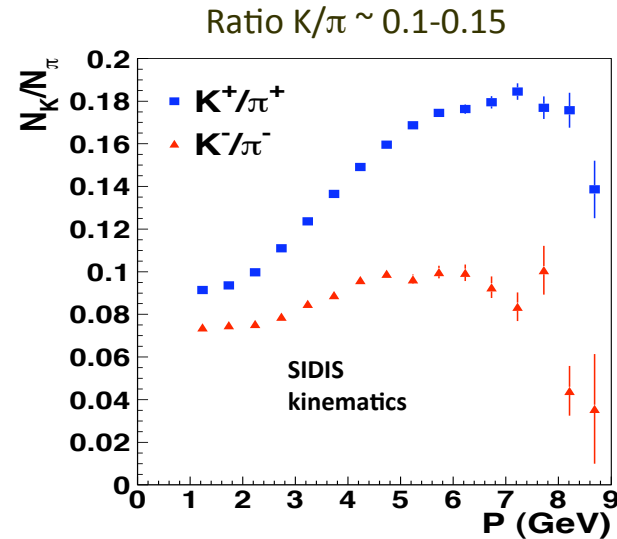
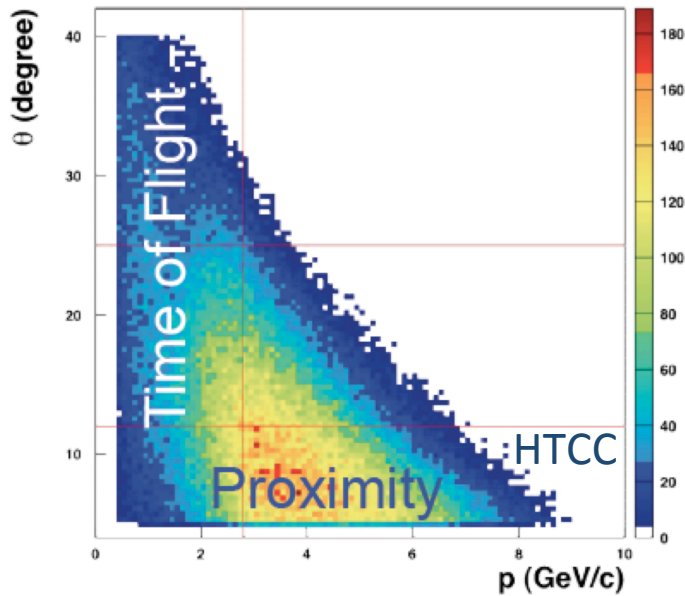
Pions in-efficiency for minimum p.e. number:

100 % below 2.7 GeV/c (Cherenkov threshold)

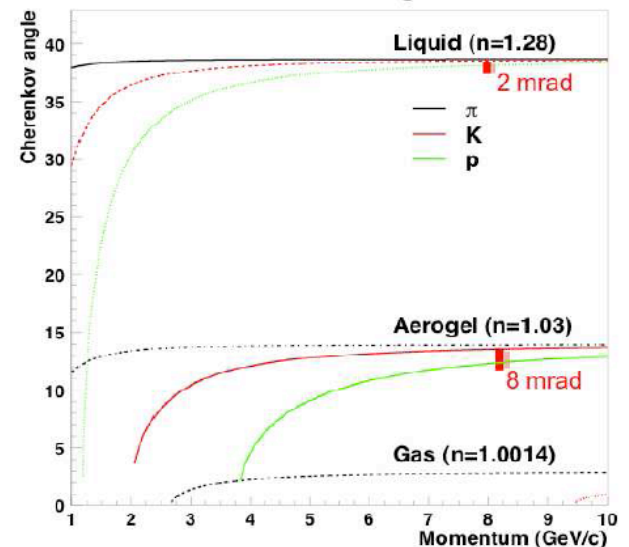
~ 10 % up to 5 GeV/c

\sim % level above 5 GeV/c

CLAS12 Momentum Range

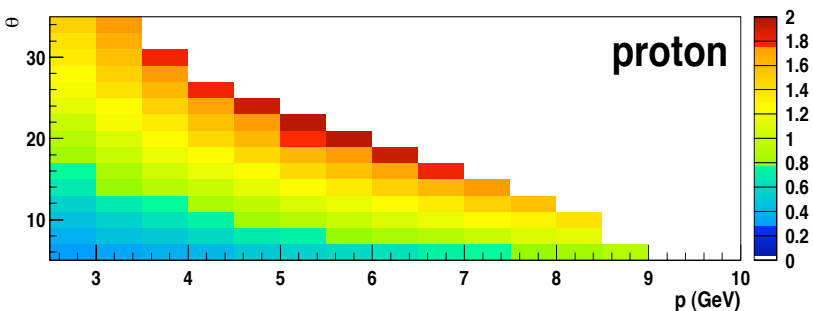
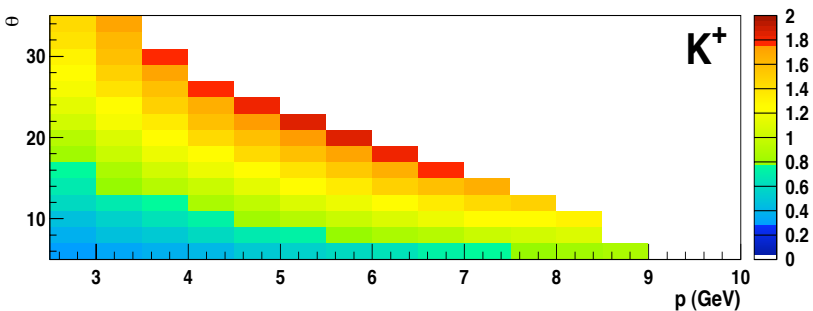
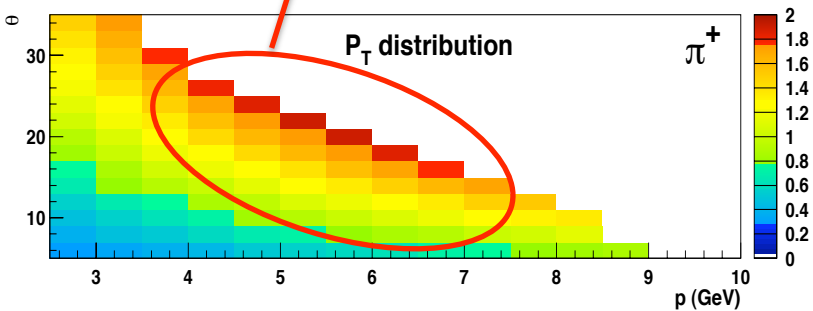


- ◆ **Aerogel** mandatory to separate hadrons in the 3-8 GeV/c momentum range with the required large rejection factors
 - collection of **visible Cherenkov light**
 - use of **PMTs**
- ◆ **Challenging project**, need to minimize detector area covered with expensive photodetectors

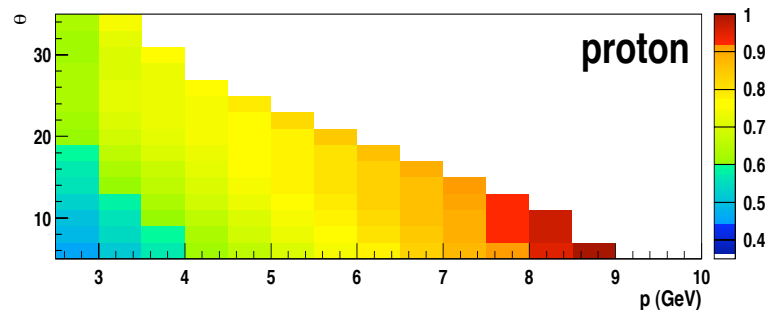
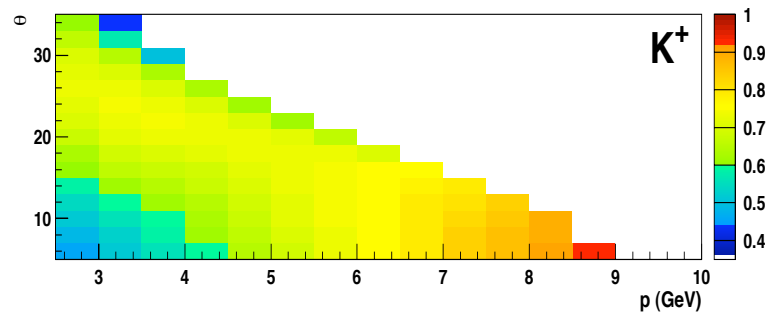
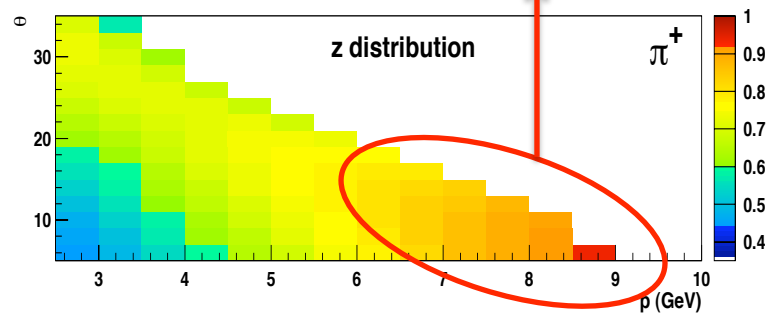


SIDIS Kinematics @ CLAS12

Intermediate angular range (15-30°) important to reach high P_T values

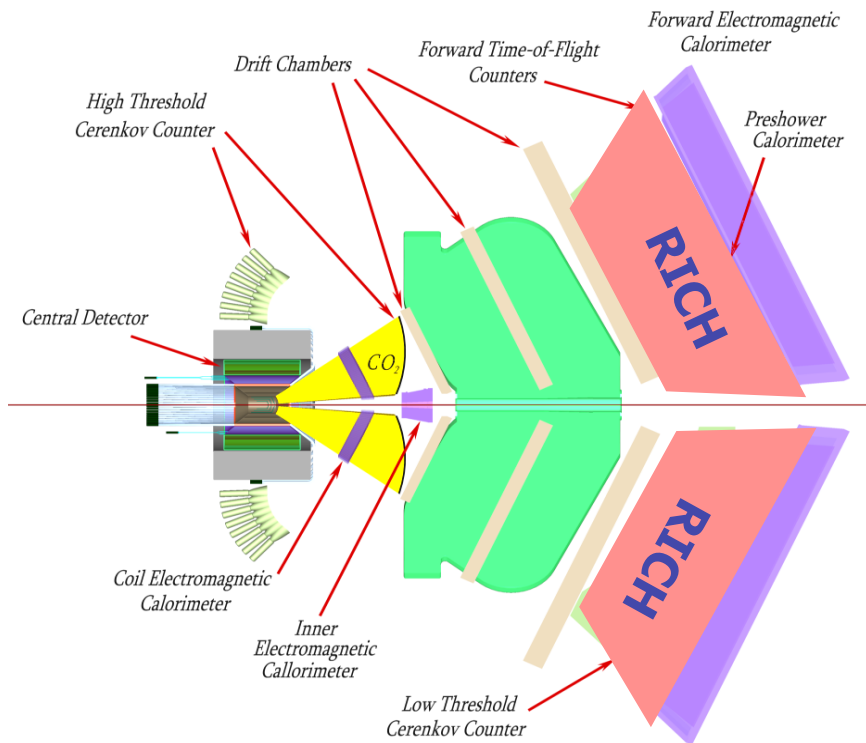


High Momentum region important as transient to hard semi-exclusive region



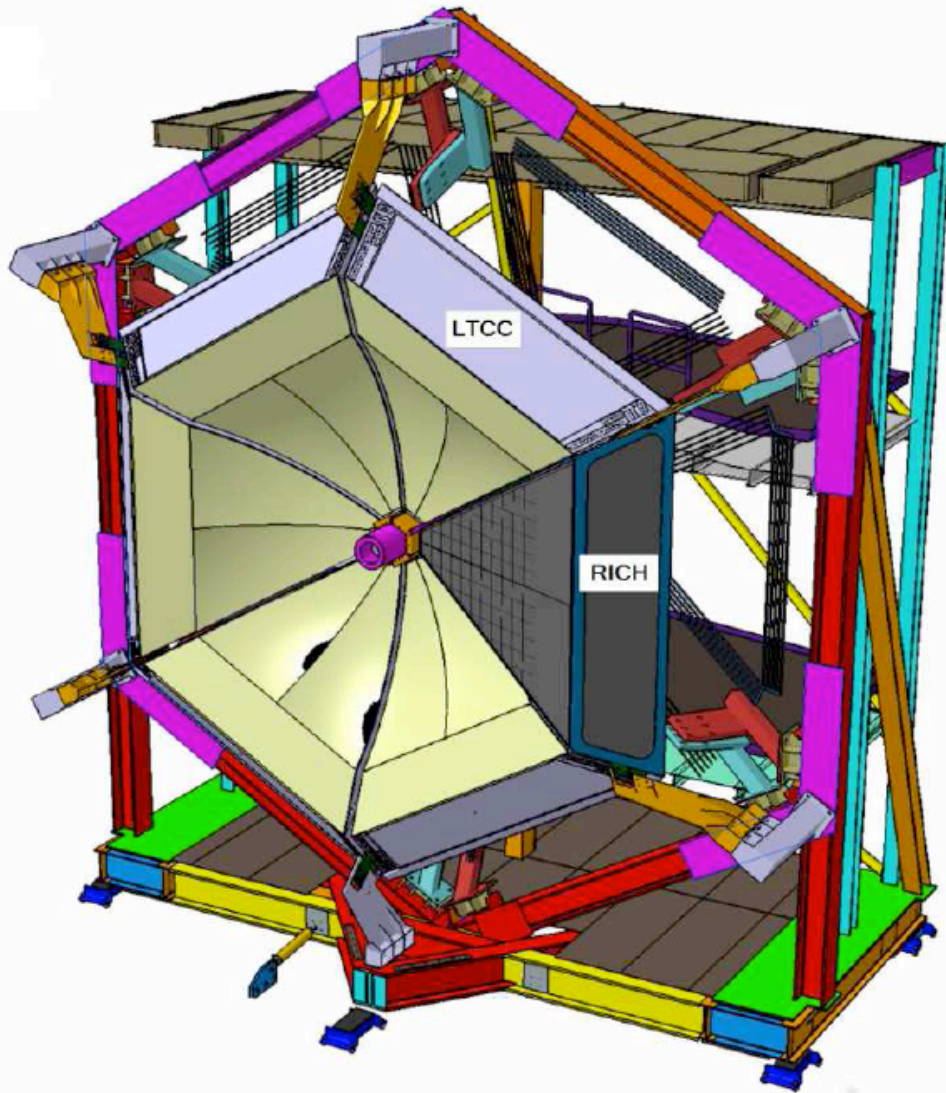
The CLAS12 RICH

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



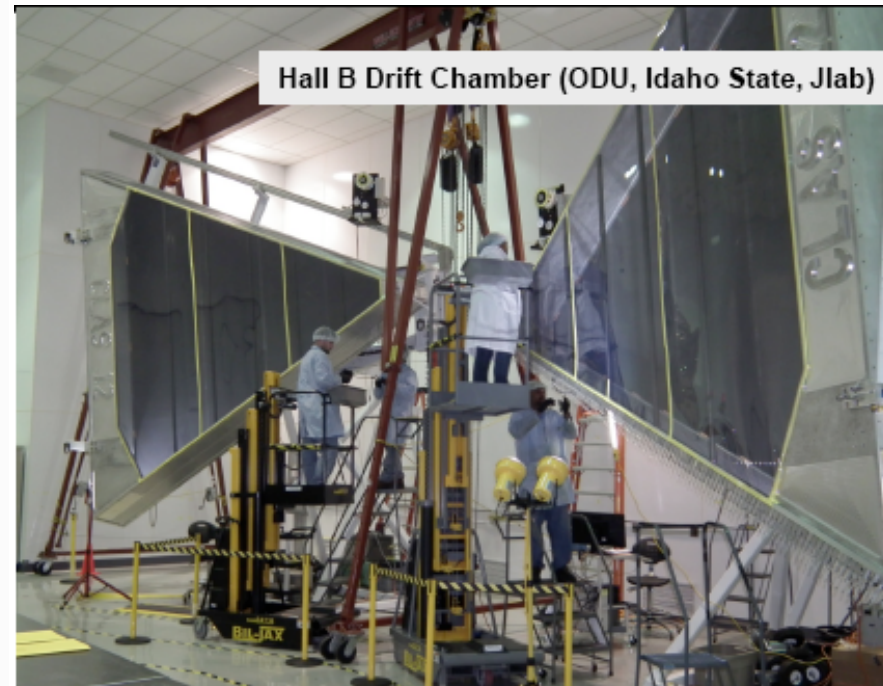
INSTITUTIONS
Jefferson Lab (Newport News, USA)
INFN (Italy) Bari, Ferrara, Genova, L.Frascati, Roma/ISS
Argonne National Lab (Argonne, USA)
Duquesne University (Pittsburgh, USA)
Glasgow University (Glasgow, UK)
J. Gutenberg Universitat Mainz (Mainz, Germany)
Kyungpook National University, (Daegu, Korea)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

RICH Base Configuration



1st sector in time for physics run
(unpolarized and longitudinal polarize targets)

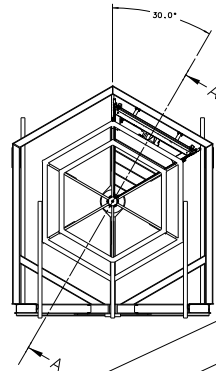
2nd++ sector for transverse target
(left-right symmetry and statistics)



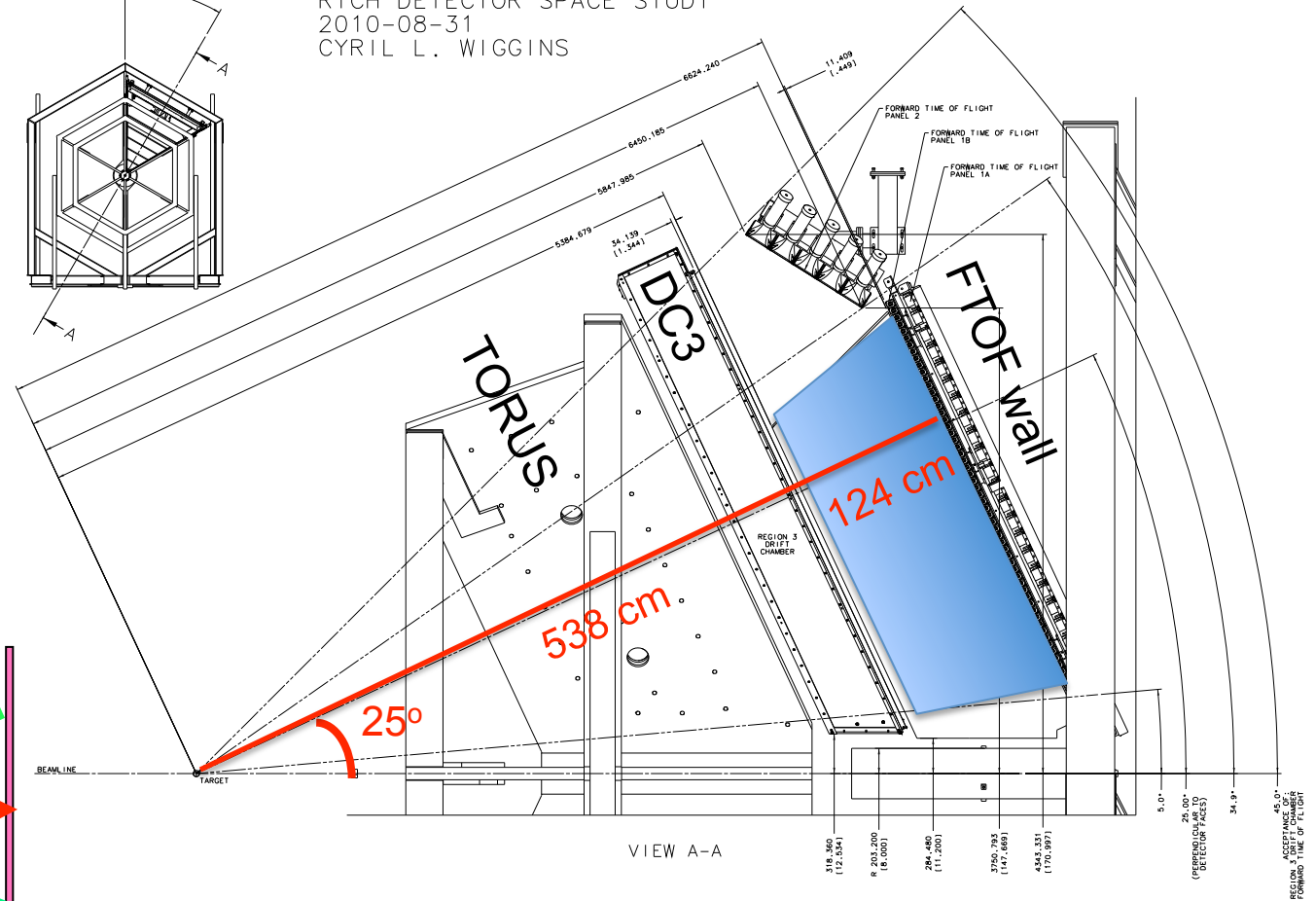
CLAS12 Geometry Constraints

Base Numbers

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



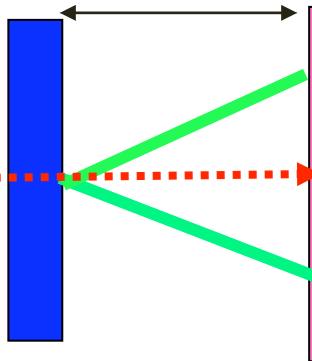
RICH DETECTOR SPACE STUDY
2010-08-31
CYRIL L. WIGGINS



Proximity RICH

Proximity gap

Charged particle



Radiator

Photon detector

RADIATOR

Aerogel Radiator



The CLAS12 large area RICH detector

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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.

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...with ...
...the main focus of ...
...imaging ...
...are ...
...describing ...
...reproduction ...
...the study of the structure ...
...of the nucleon and quark hadronization processes [2].

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 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 wave 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,

...rejection factor ...
...signal ...
...detectors do ...
...the 5–8 GeV ...
...tion and event reconstruction ...
...range by replacing ...
... (LTCC) with a RICH ...
...design of CLAS12.

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.

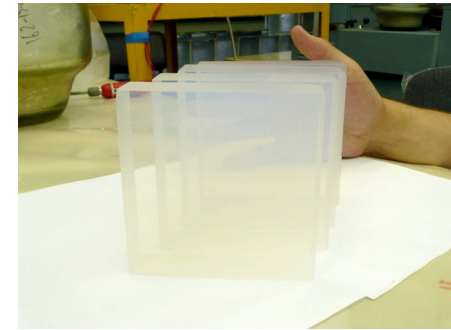
A setup similar to the one adopted in Hall-B (C₅F₁₂ or C₆F₁₄) radiator and a CsI-deposited on a cylindrical chamber as a UV-photon detector, is required pion rejection factor at momenta up to 8 GeV/c.

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

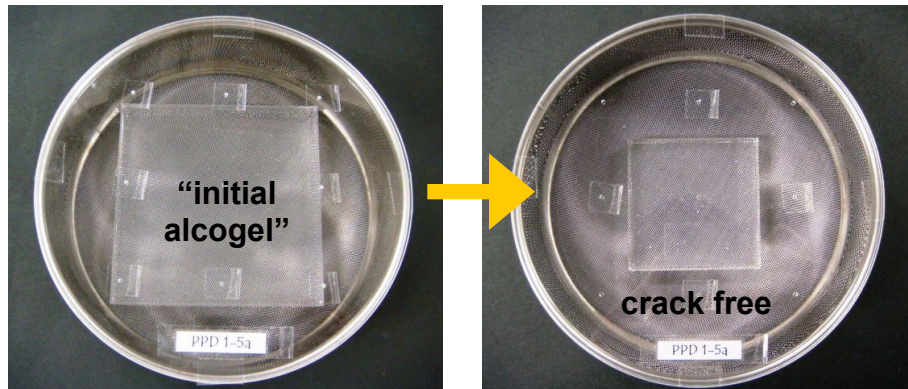
* Corresponding author.
E-mail address: mcontal@fe.infn.it

Aerogel Transmission Length

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



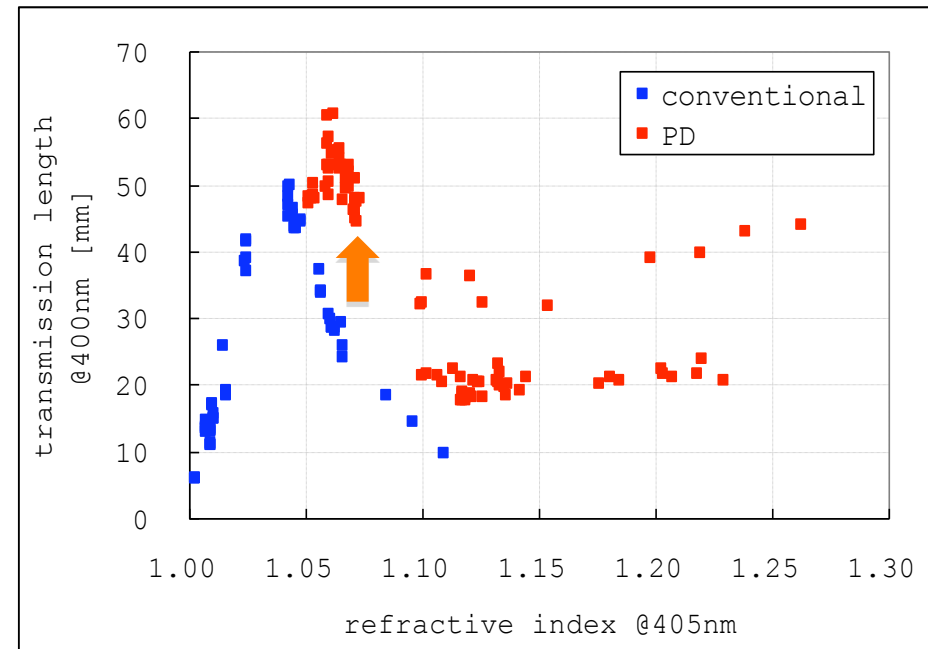
M. Tabata @ RICH 2010



pinhole drying process

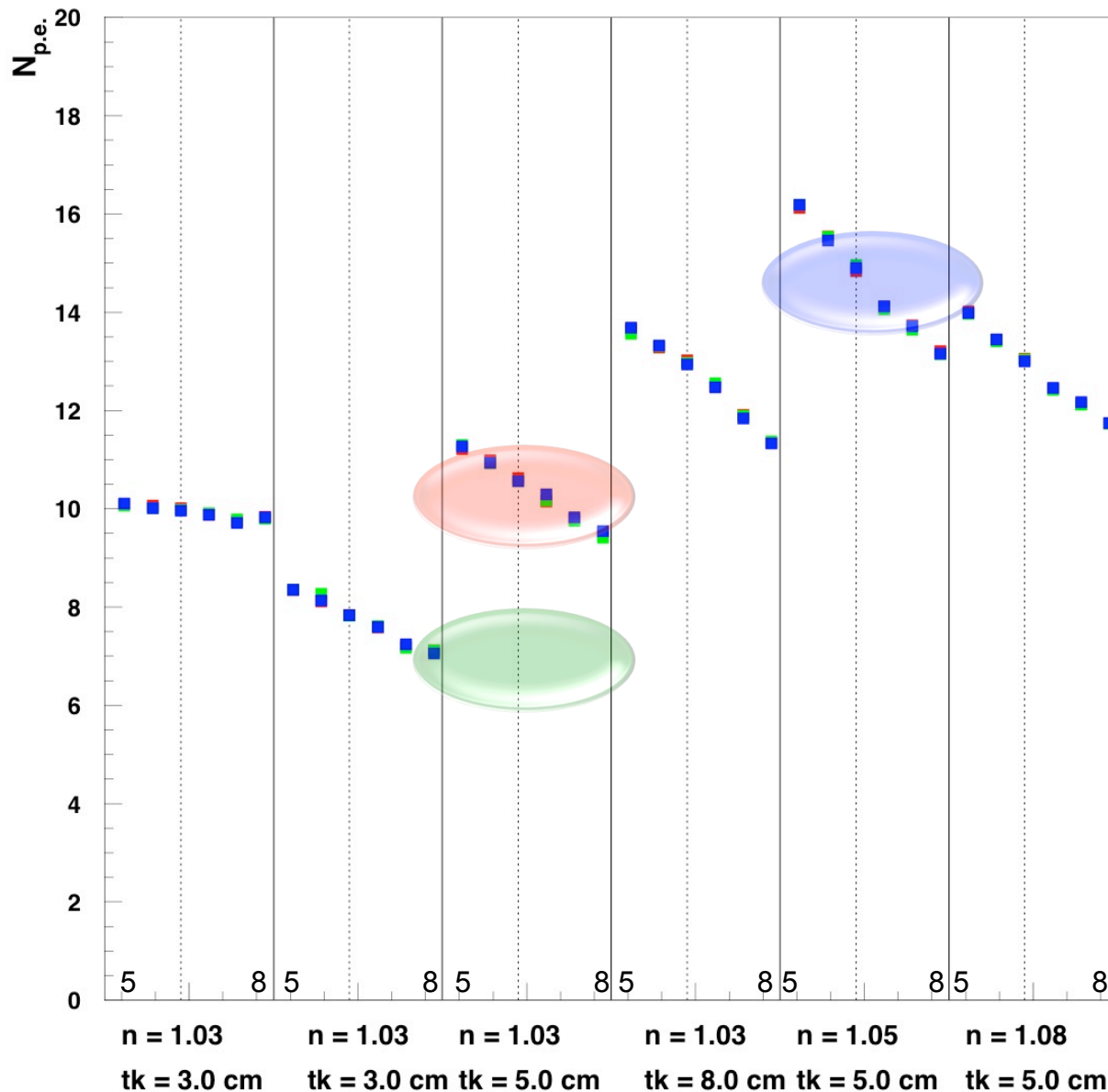
A.F. Danilyuk @ RICH 2010

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



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

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

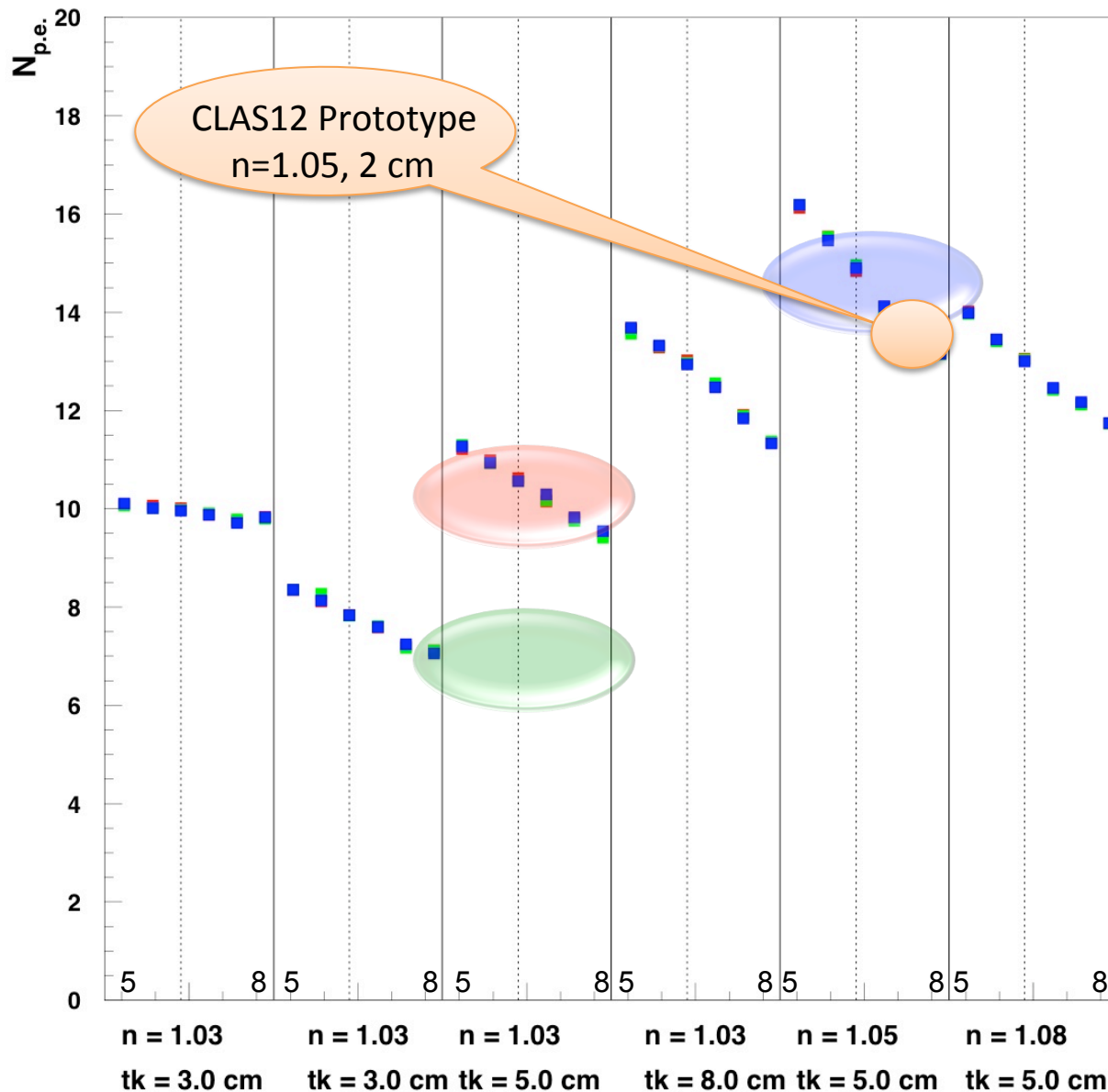


BELLE II test-bench
15 p.e. with aerogel of
 $n \sim 1.05$ refractive index
and 4 cm thickness

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

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



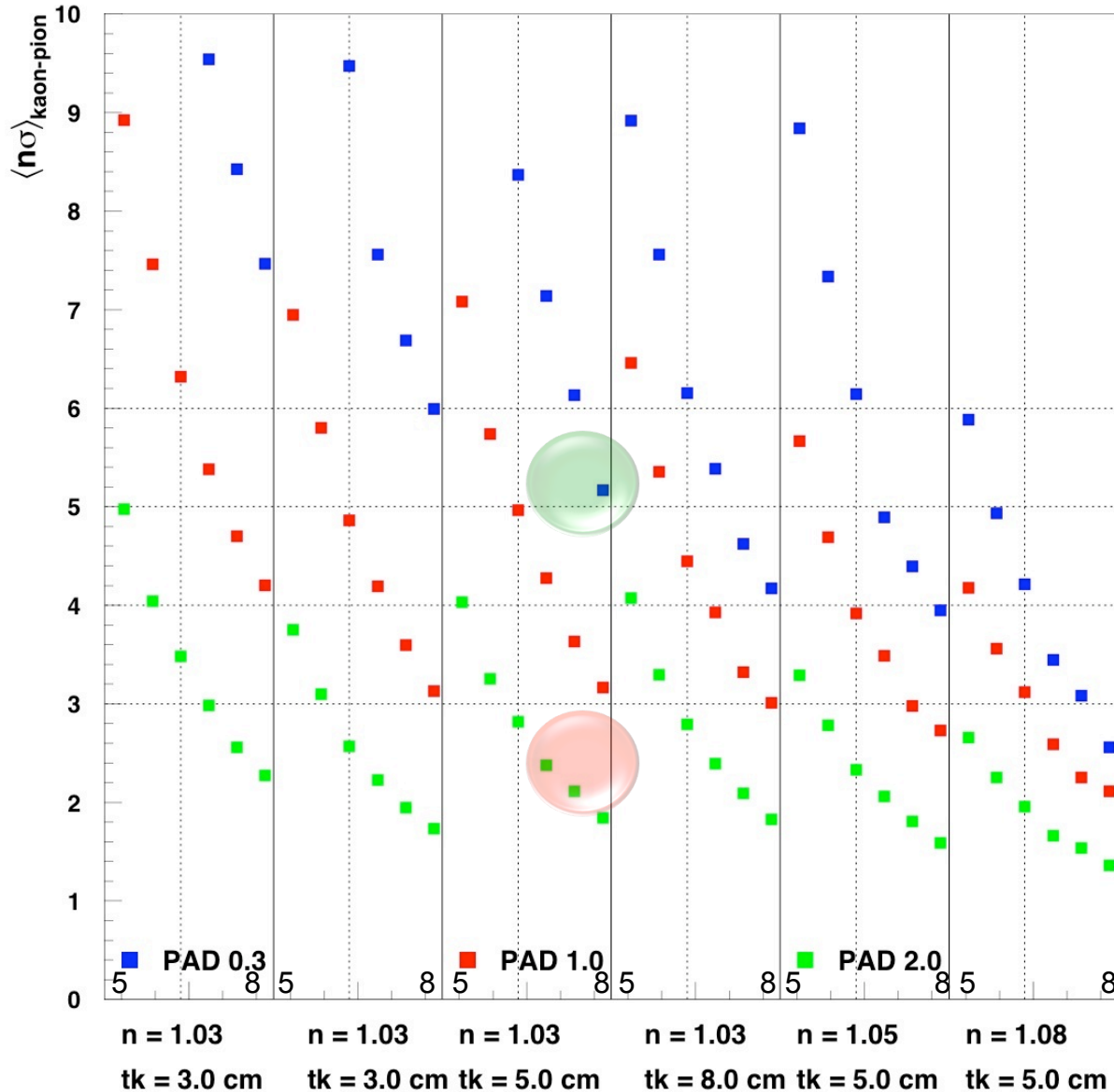
BELLE II test-bench
15 p.e. with aerogel of
n ~ 1.05 refractive index
and 4 cm thickness

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

P (GeV/c)

Mean π/K Separation (5-8 GeV/c)

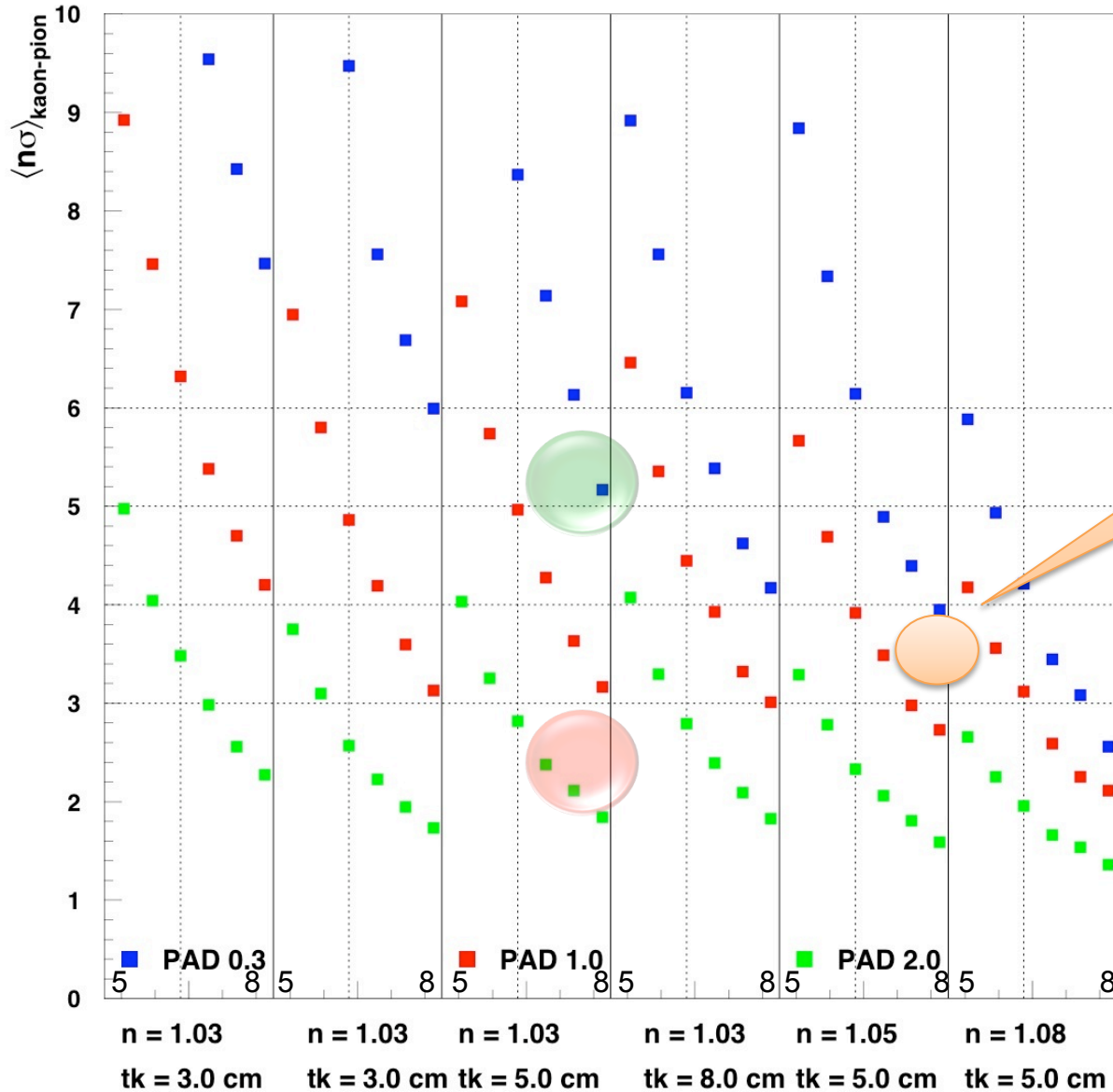


LHC-B
 3 mrad single photon
 resolution with ~ 3 mm
 comparable pixel size

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)



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

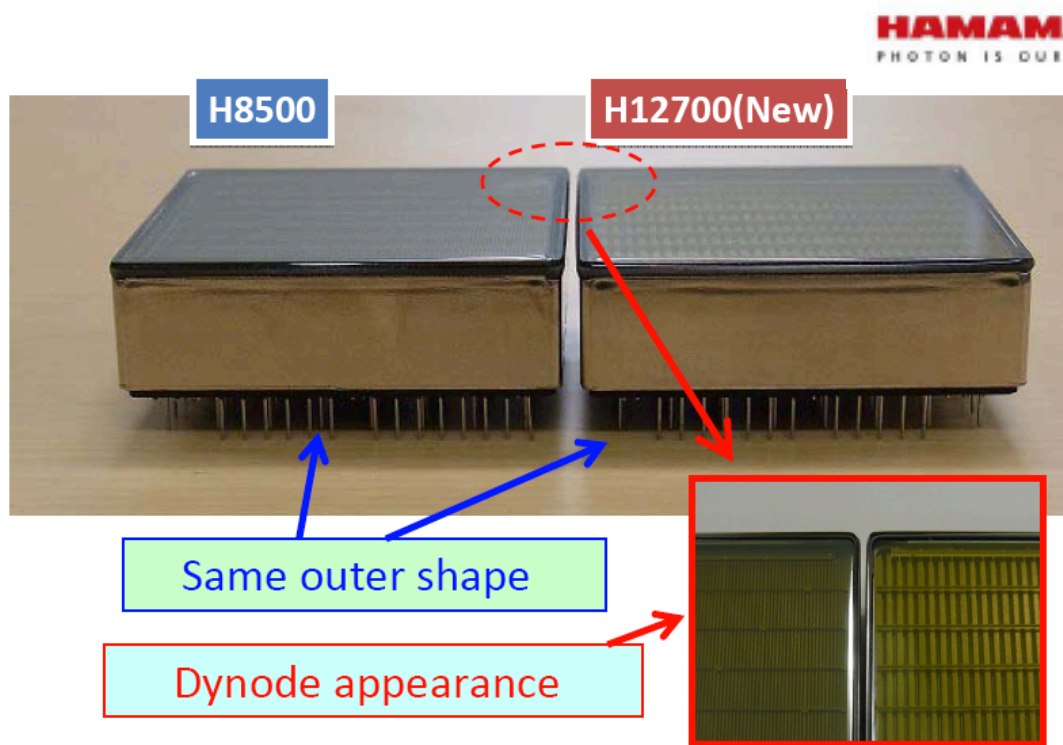
7.6 mrad single photon
 resolution, dominated
 by the ~ 2 cm pixel size

P (GeV/c)

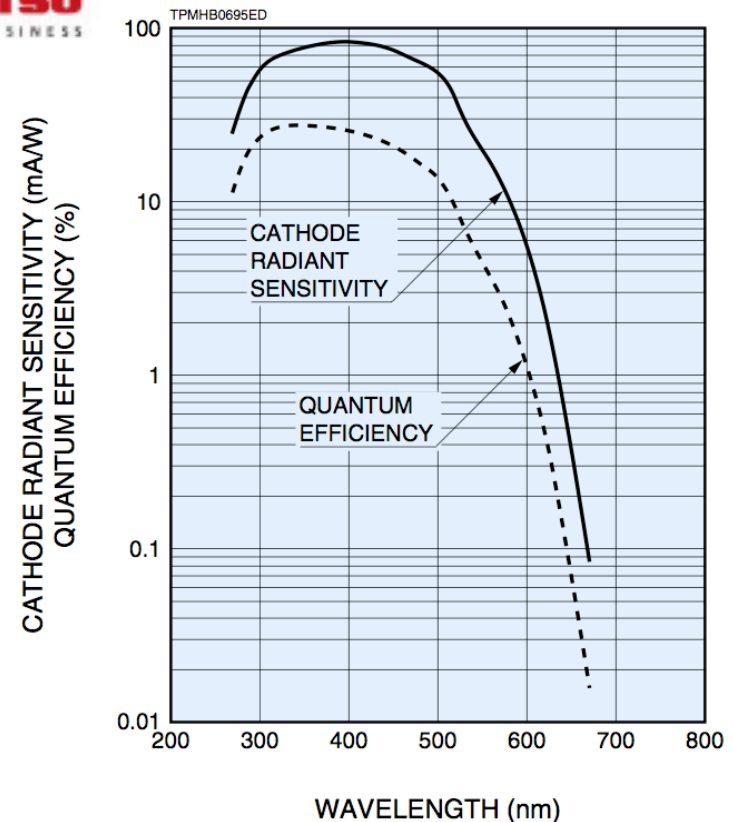
PHOTODETECTOR

Photon Detectors: MA-PMT

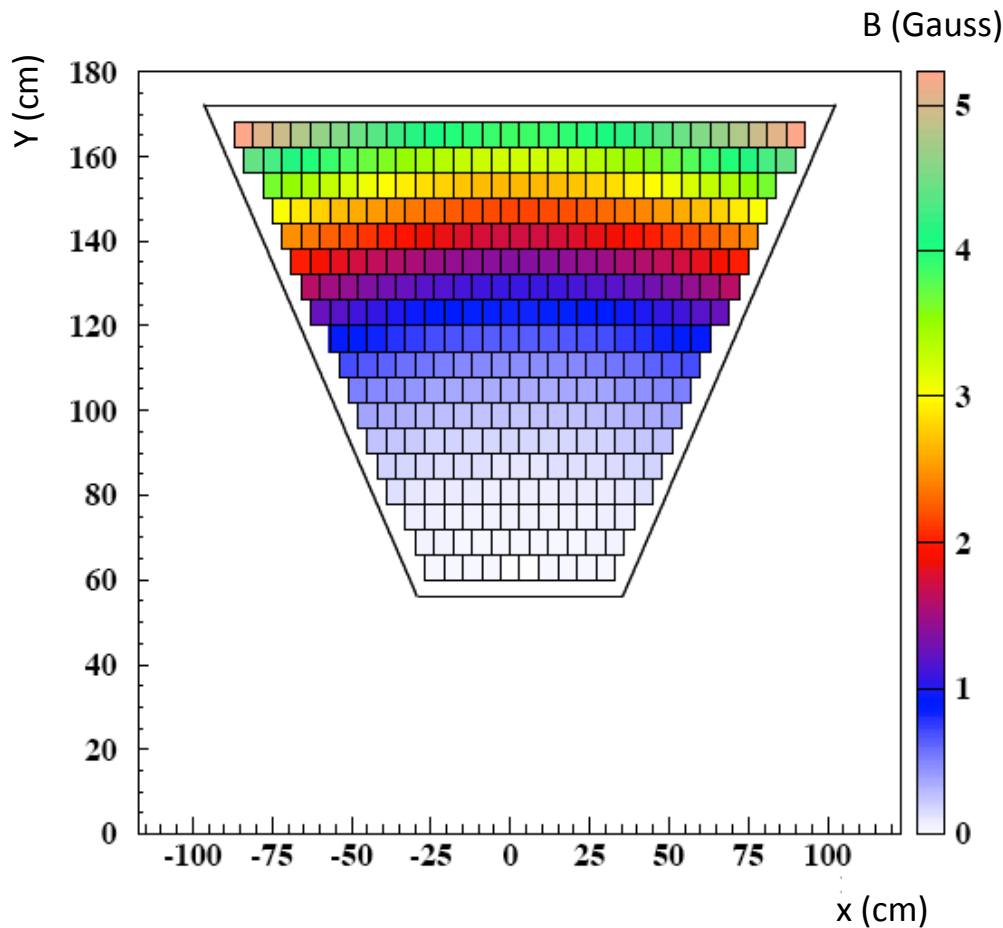
Multi-Anode Photomultipliers: Large Area (5x5 cm²)
Cost-Effective Devices (~2.3 k\$ each)
High packing density (89 %)



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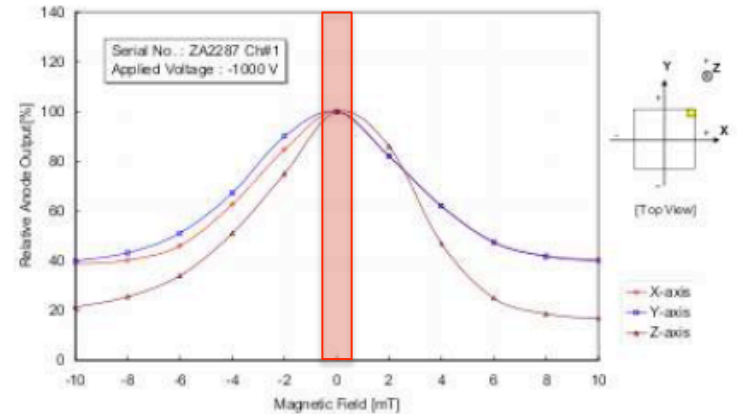


Magnetic Field



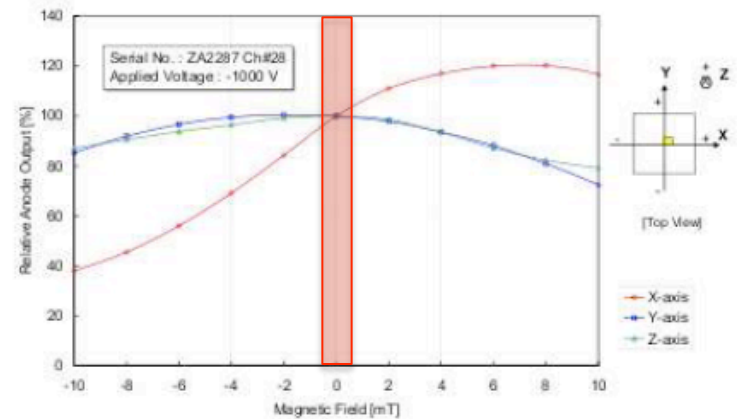
HAMAMATSU
HAMAMATSU PHOTONICS K.K. Electron Tube Division

H8500 Magnetic Field Characteristics



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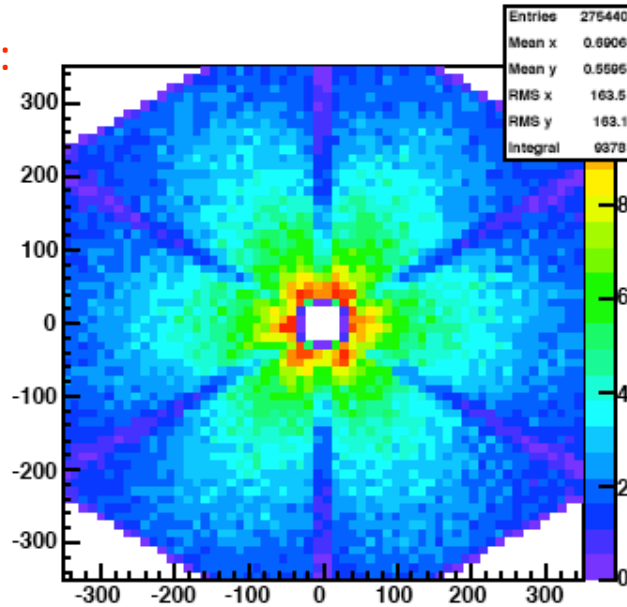
H8500 Magnetic Field Characteristics



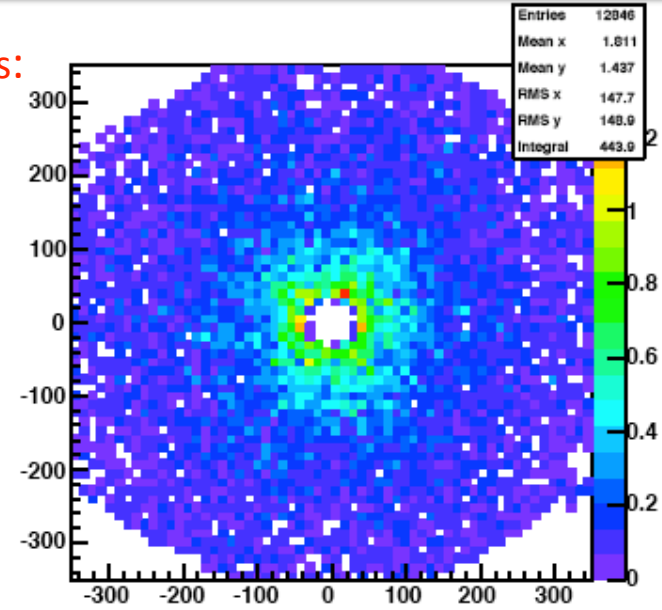
The torus fringe-field allows the use of Multi-Anode Photomultipliers

Radiation Damage

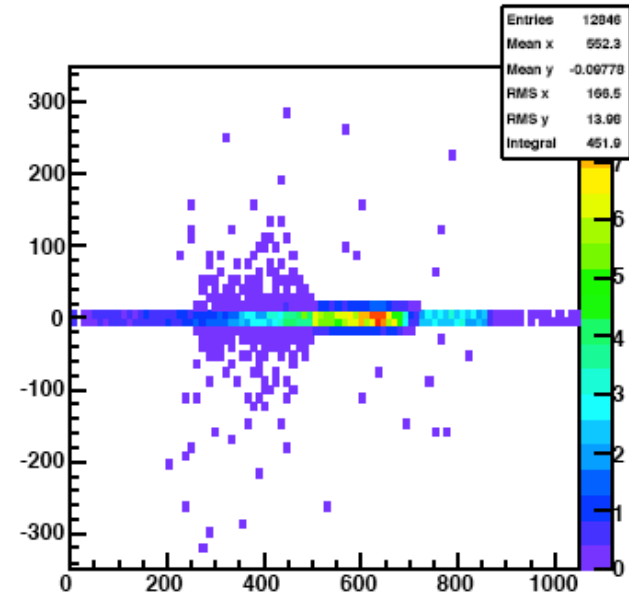
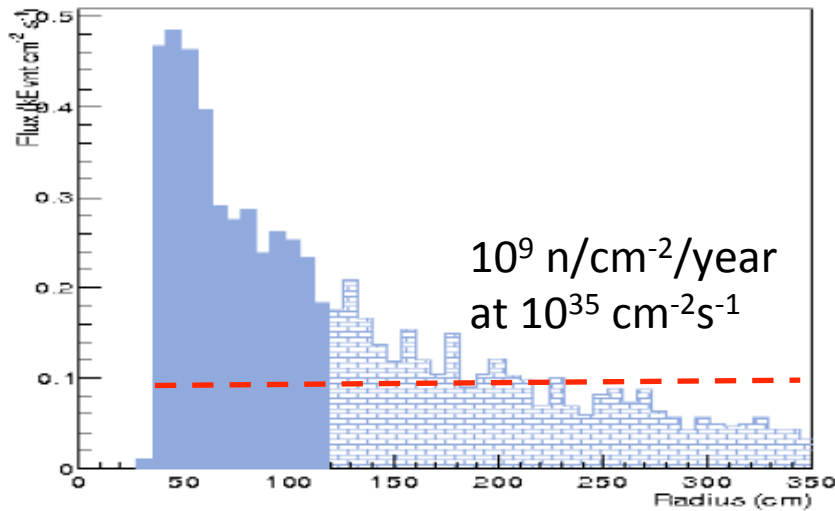
Gammas:



Neutrons:



Neutrons:

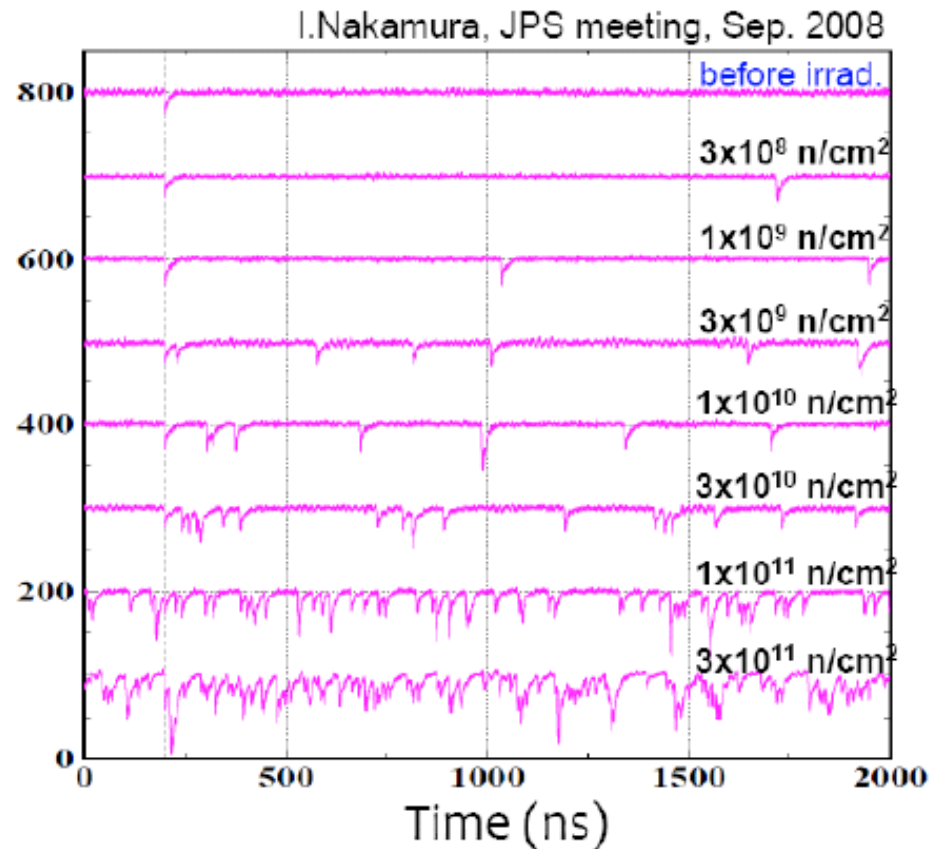
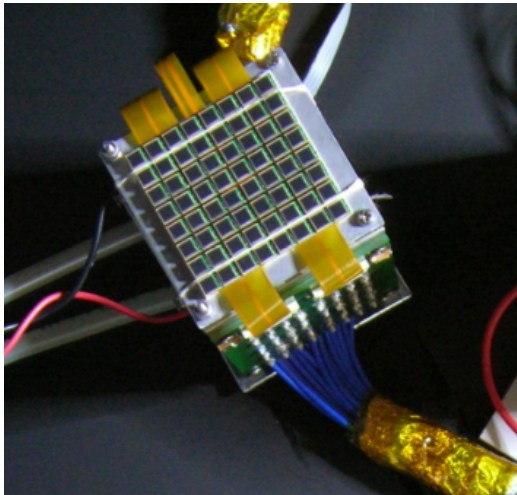


Photon Detectors: SiPM

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

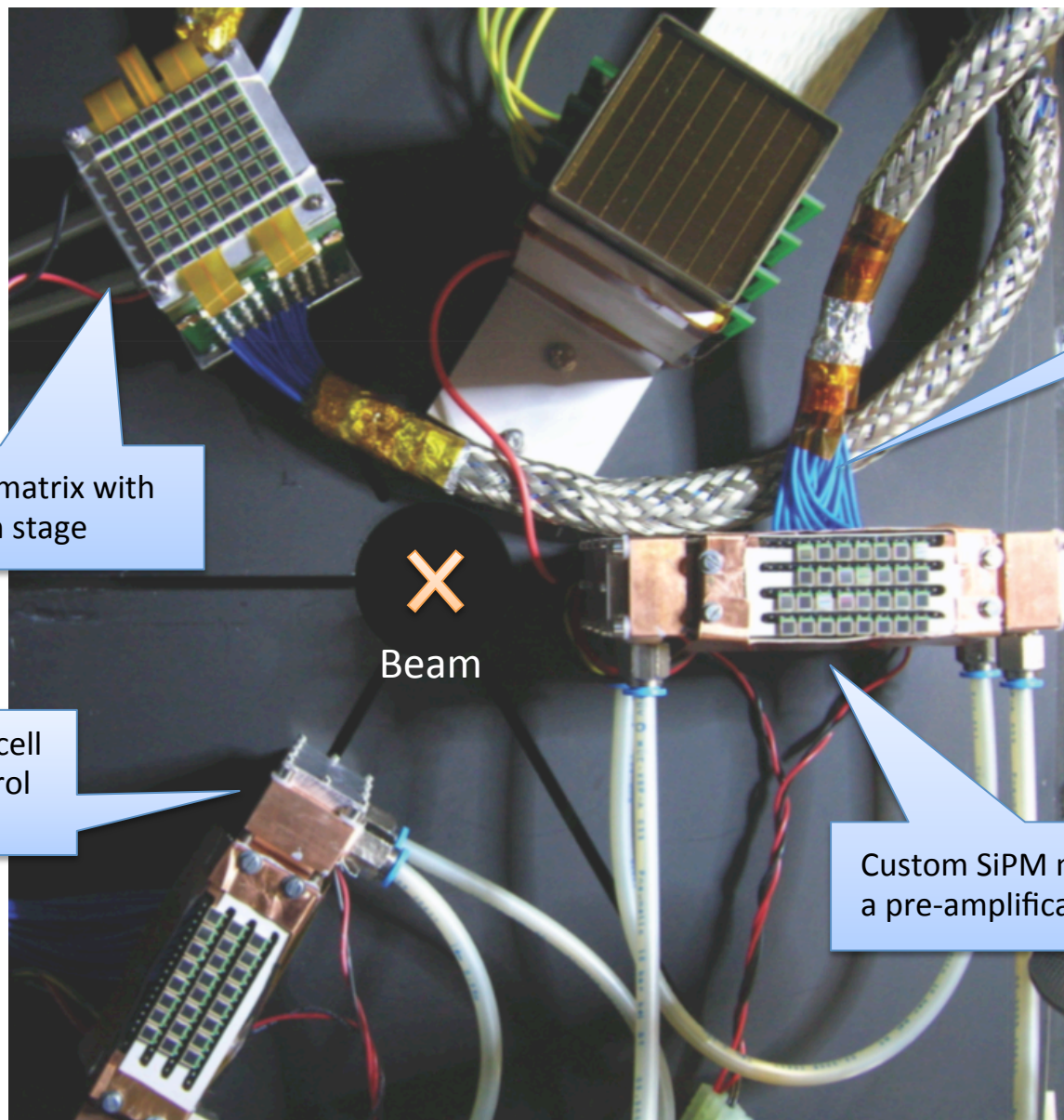
Expected fluence @ LHCb-2:
1 year \rightarrow 6 10^{11} n/cm²



Fluence at CLAS12 allows the use of SiPM for future upgrades:

- ✓ fast development in performances (dark count \sim 1 MHz for 3x3 mm² devices)
- ✓ fast reduction in price (already comparable with MA-PMTs over 1 m²)
- ✓ require dedicated R&D for electronics and cooling

The SiPM Test Prototype



Commercial SiPM matrix with a pre-amplification stage

1.5 m coaxial cables to the electronics

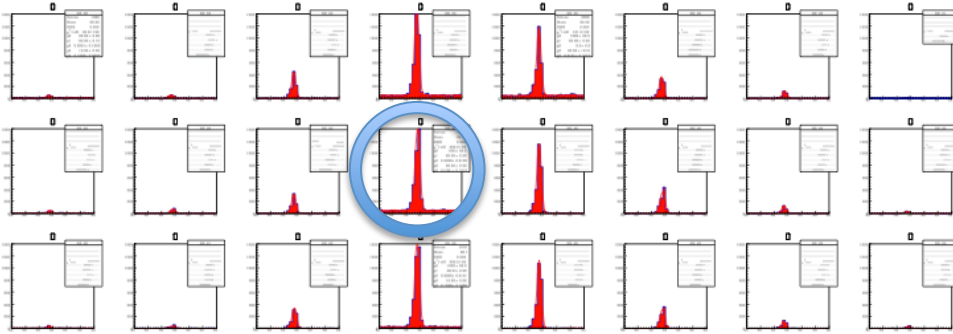
X
Beam

Water-cooled Peltier cell for temperature control [-25 : +25 Celsius]

Custom SiPM matrices with a pre-amplification stage

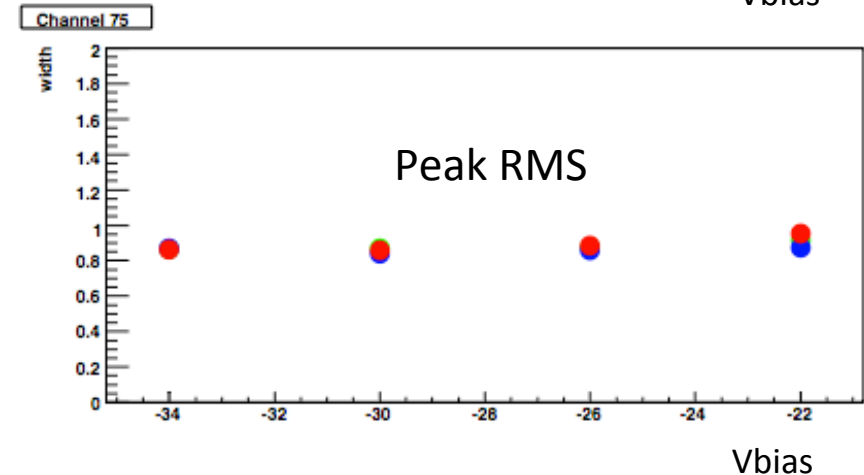
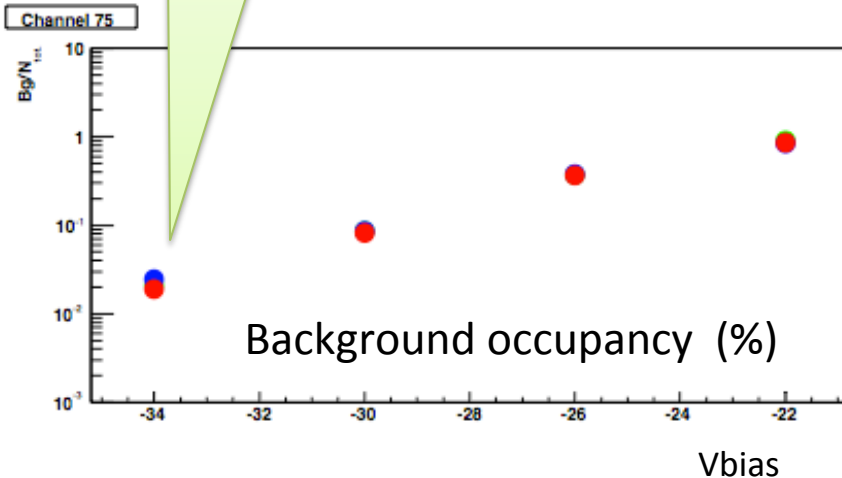
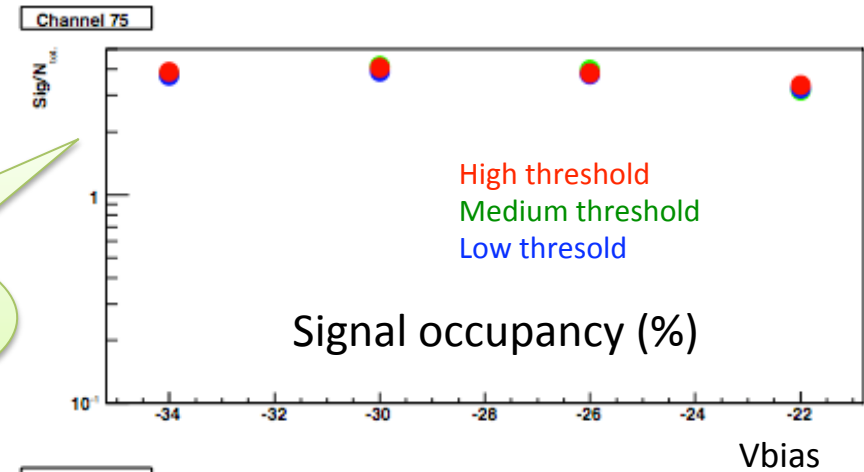
The Custom SiPM Matrix@-25°

For a 12 cm radius Cherenkov cone and a 3 mm SiPM pixel, an occupancy of 4 % corresponds to about 24 p.e.



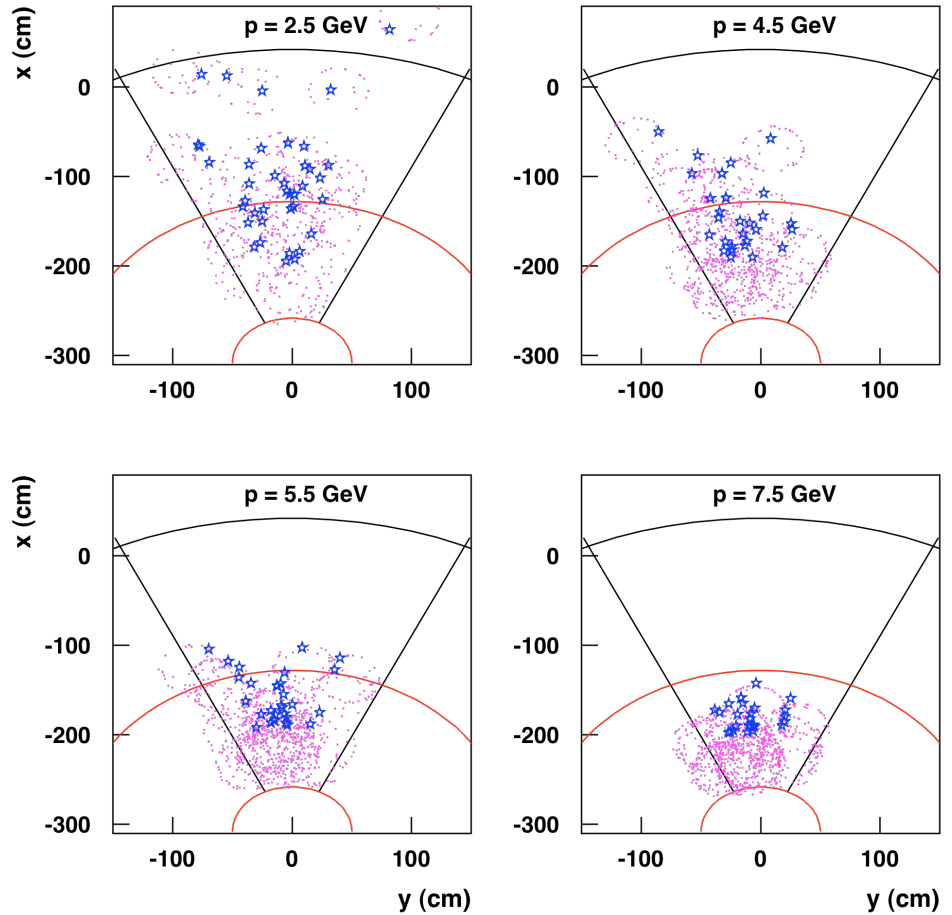
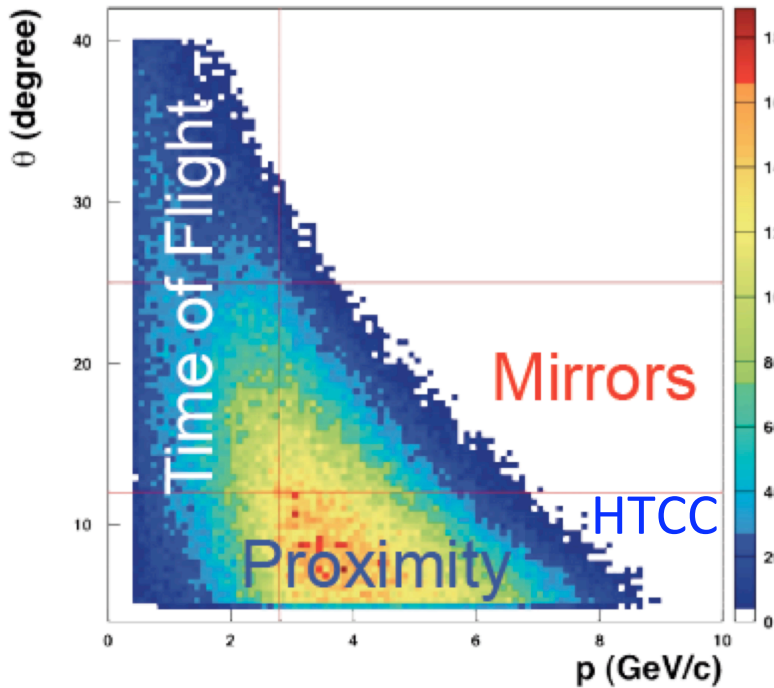
In a +/- 3 ns window
Comparable with H8500

Largely insensitivity to
Vbias and discriminator
threshold

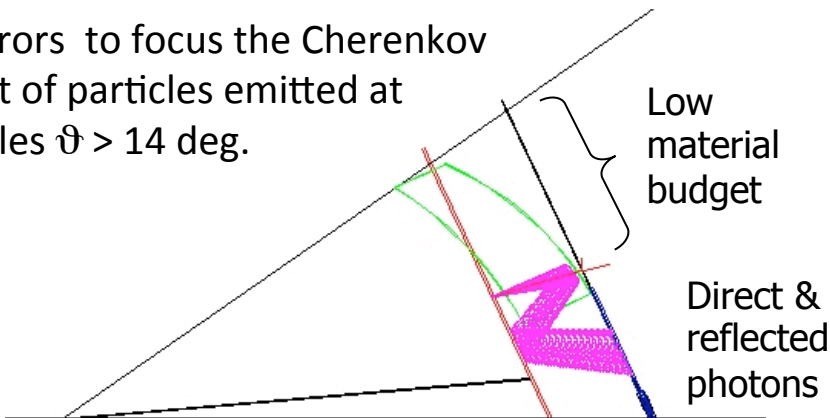


THE MIRROR SYSTEM

The Mirror System



Mirrors to focus the Cherenkov light of particles emitted at angles $\vartheta > 14$ deg.

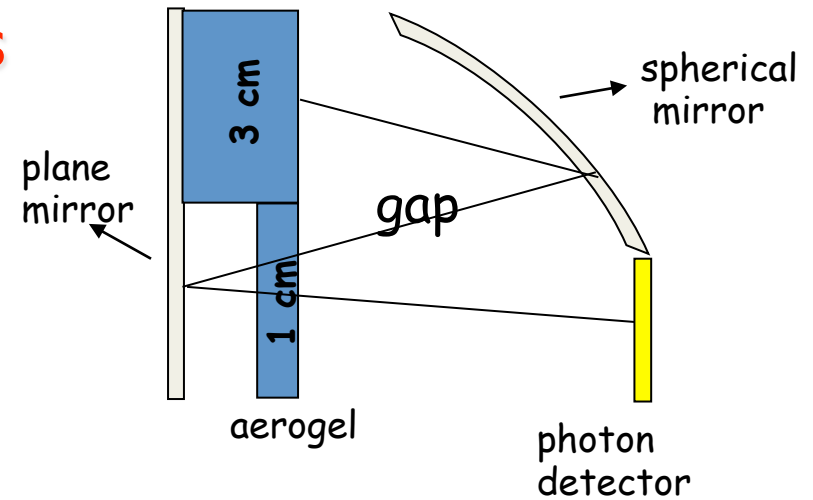
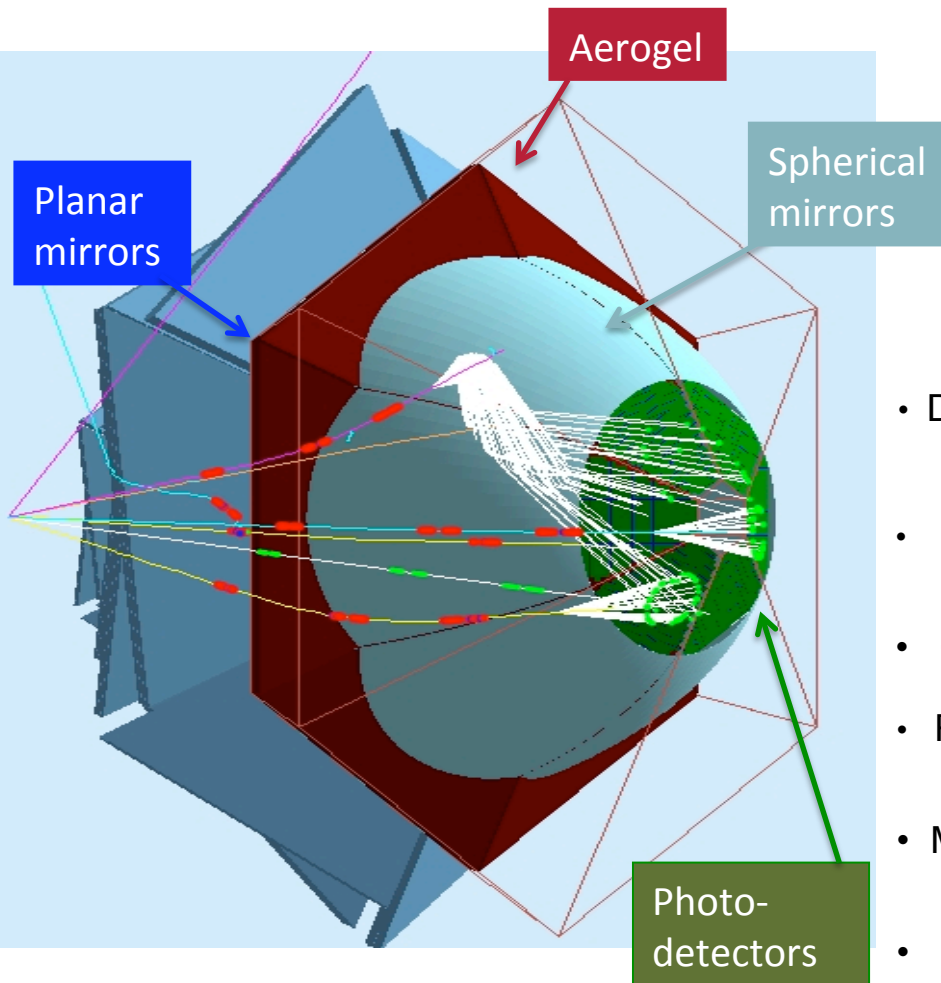


Goals:

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

The Mirror System

Proximity Focusing RICH + Mirrors

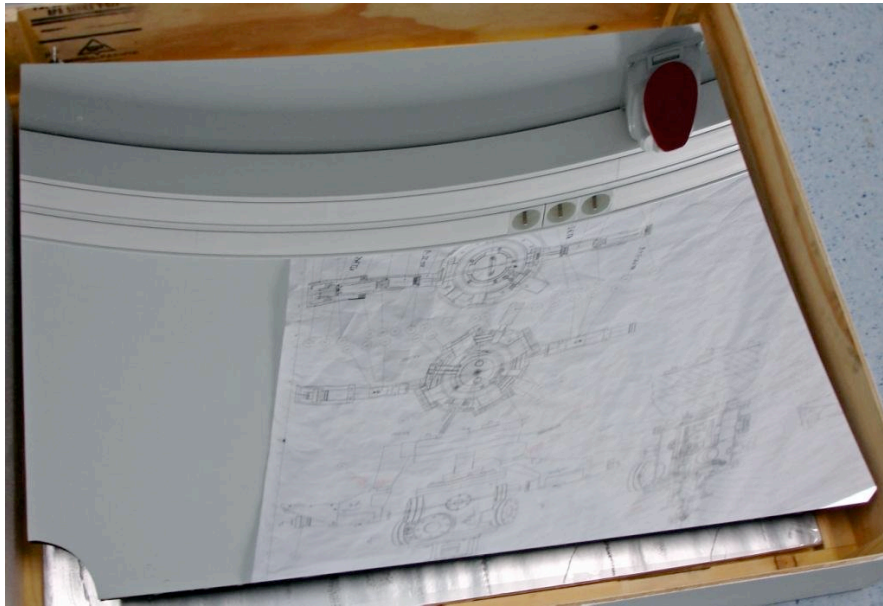


- Direct rings for high momentum particle
→ best performance !
- Minimize photon detector area → cost !
- **Open detector close to beam line → background !**
- Reflected rings for low momentum particle
→ less demanding
- Minimum interference with TOF
- **Multiple passages within aerogel → photon losses**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

Mirror Technology

Metalized Carbon Fiber substrate

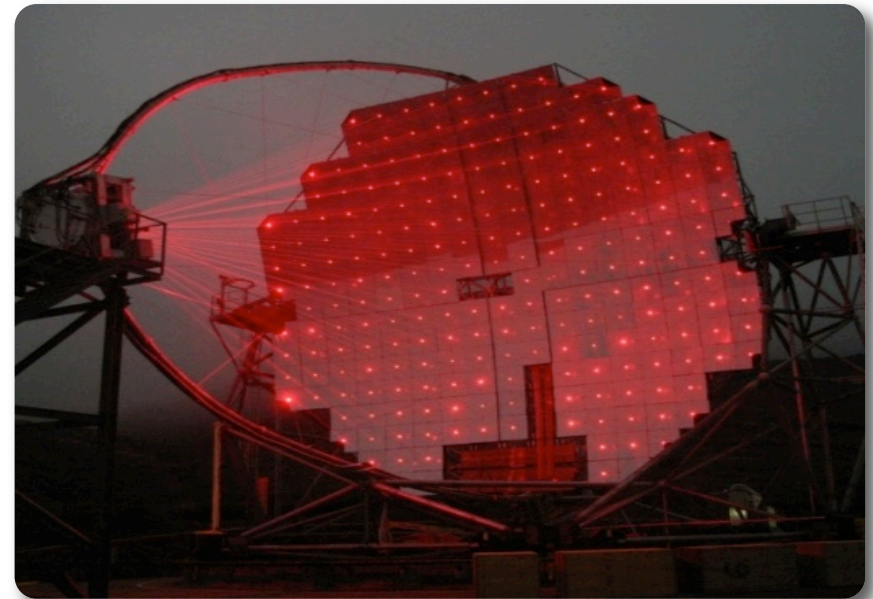
Self-supporting structure with
minimal material budget
(applications in physics experiments)



LHCB mirror

Thin glass skin embracing a honeycomb core

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



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

RICH outlook

Summer 2013:

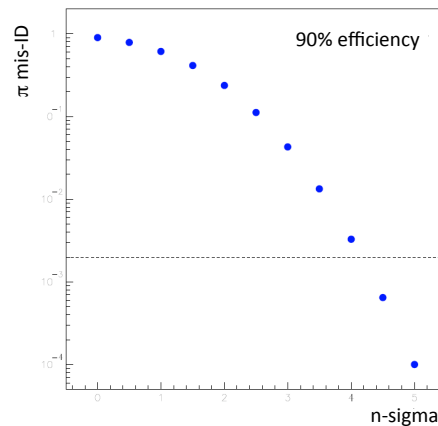
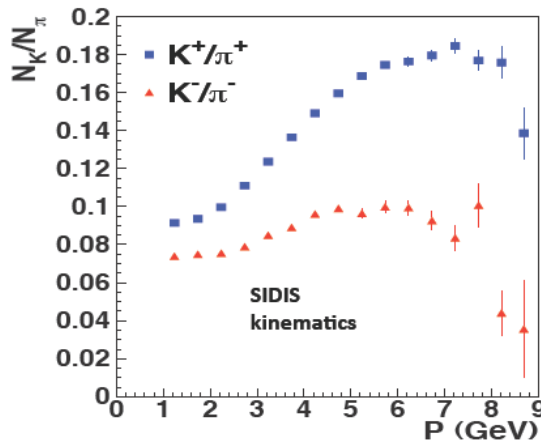
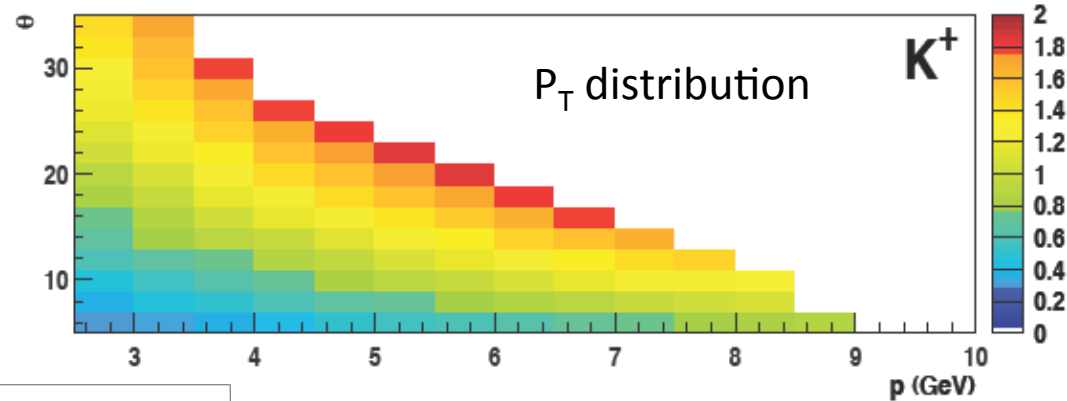
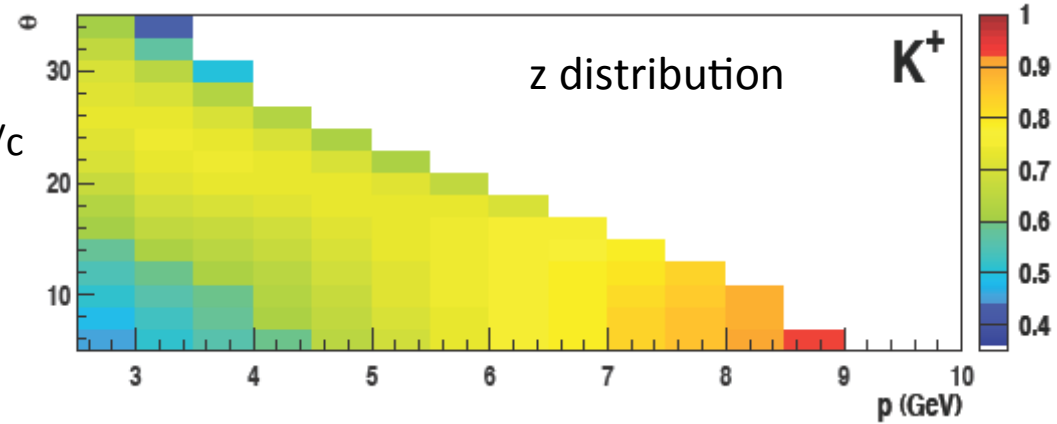
- ✓ August: Finalize CLAS12 RICH Project (TDR)
- ✓ 5-6 September: Project Review with DOE
- ✓ September: Start Procurement

GOAL: 1st sector ready for physics run in 2016

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



Pion rejection close to 500
 Proton rejection close to 100
 To contain contamination at the few % level