RICH Project Overwiev

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INFN Ferrara

Rich Project Review, 5^{th} September 2013

The CLAS12 Spectrometer

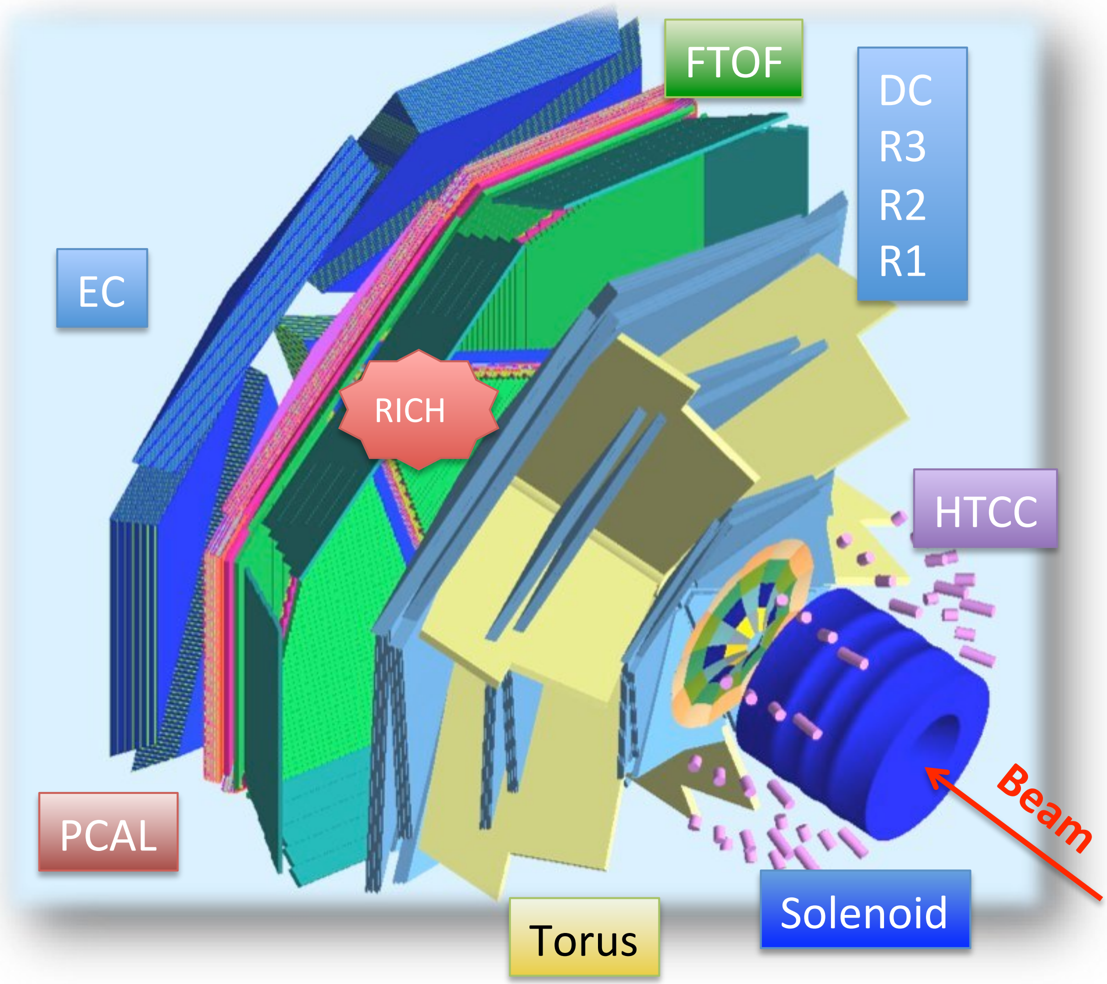
Luminosity up to 10^{35} cm^{-2} s^{-1}

Highly polarized electron beam

H and D polarized targets

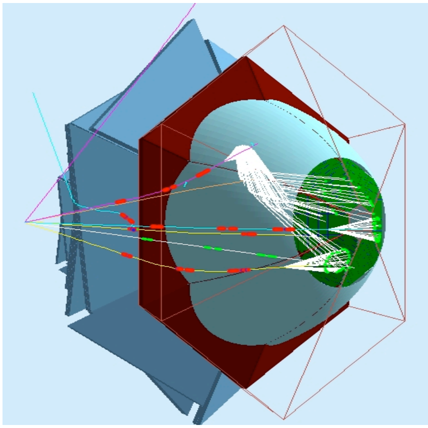
Broad kinematic range coverage
(current to target fragmentation)

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

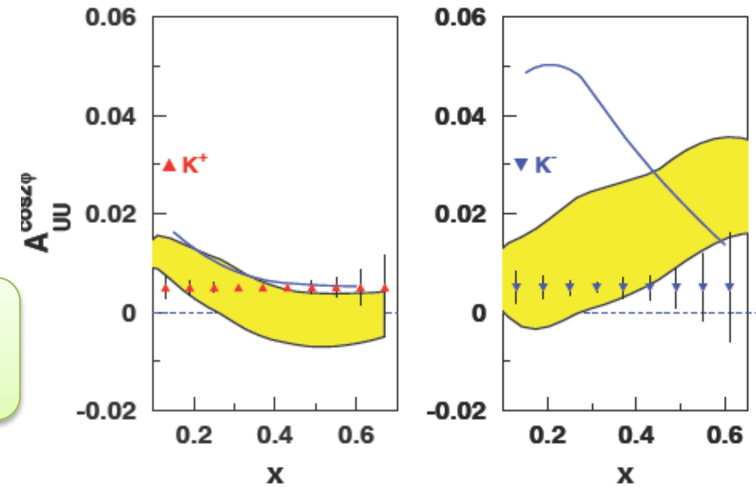


PAC30 report (2006): Measuring the kaon asymmetries is likely to be as important as pions …. The present capabilities of the present CLAS12 design are weak in this respect and should be strengthened.

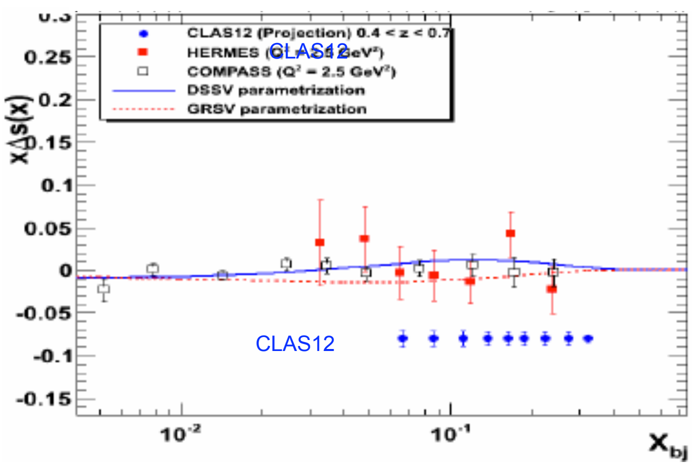
Kaon SIDIS Program @ CLAS12



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

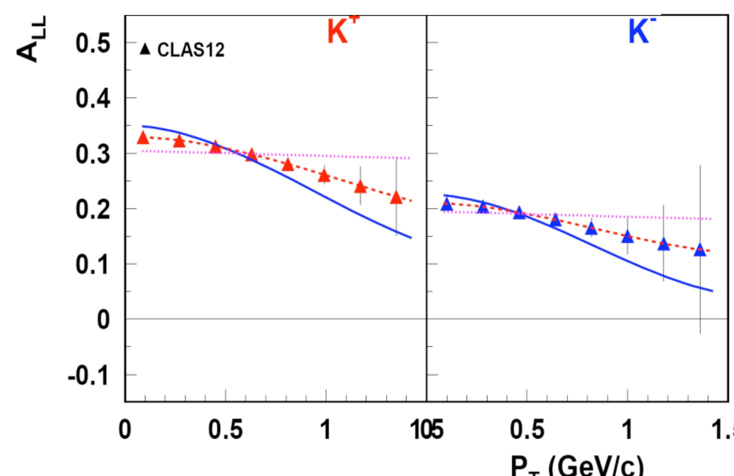


E12-09-09:

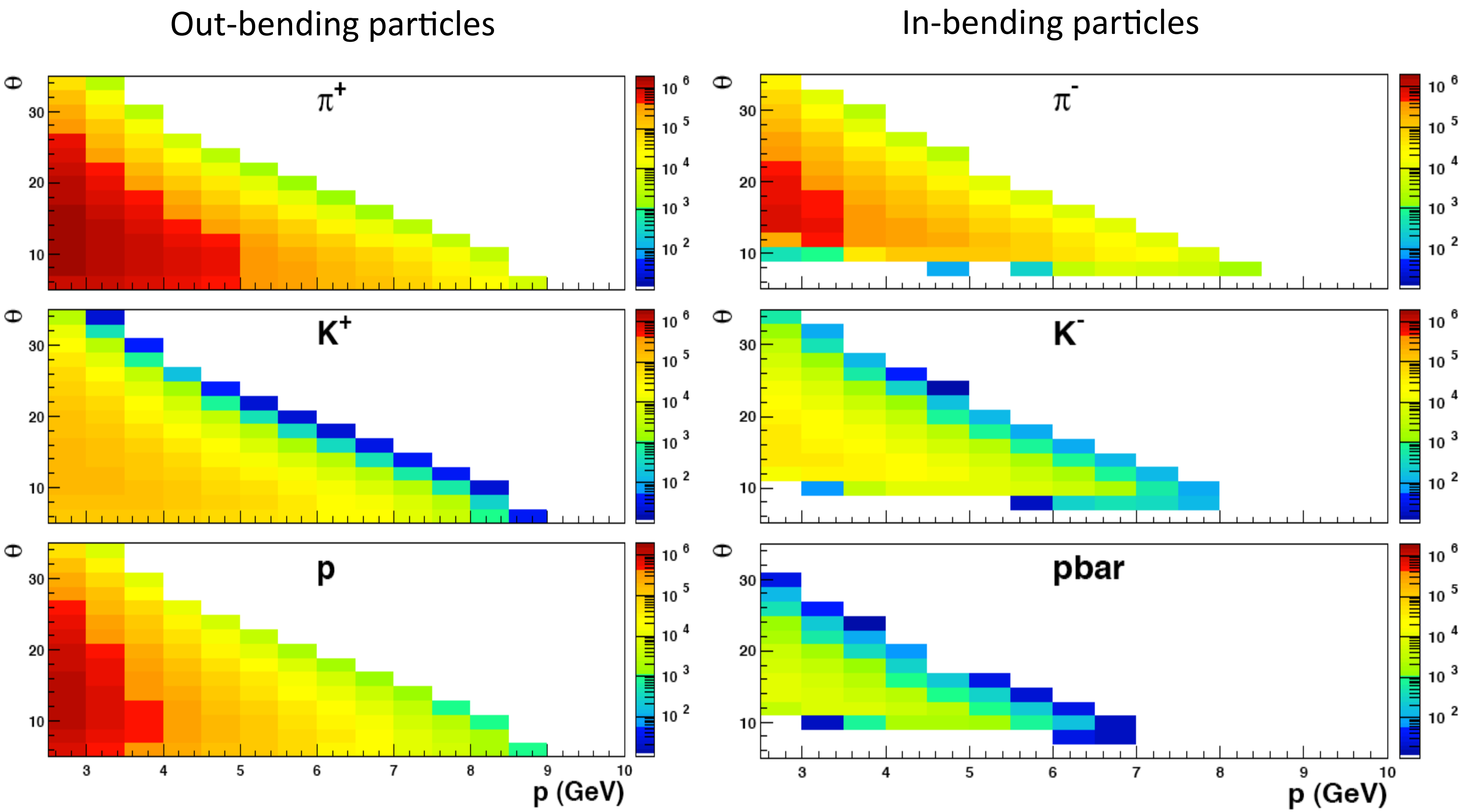
Studies of Spin-Orbit Correlations in Kaon Electroproduction in DIS with polarized hydrogen and deuterium targets

E12-09-07:

Studies of partonic distributions using semi-inclusive production of Kaons



SIDIS Kinematics @ CLAS12

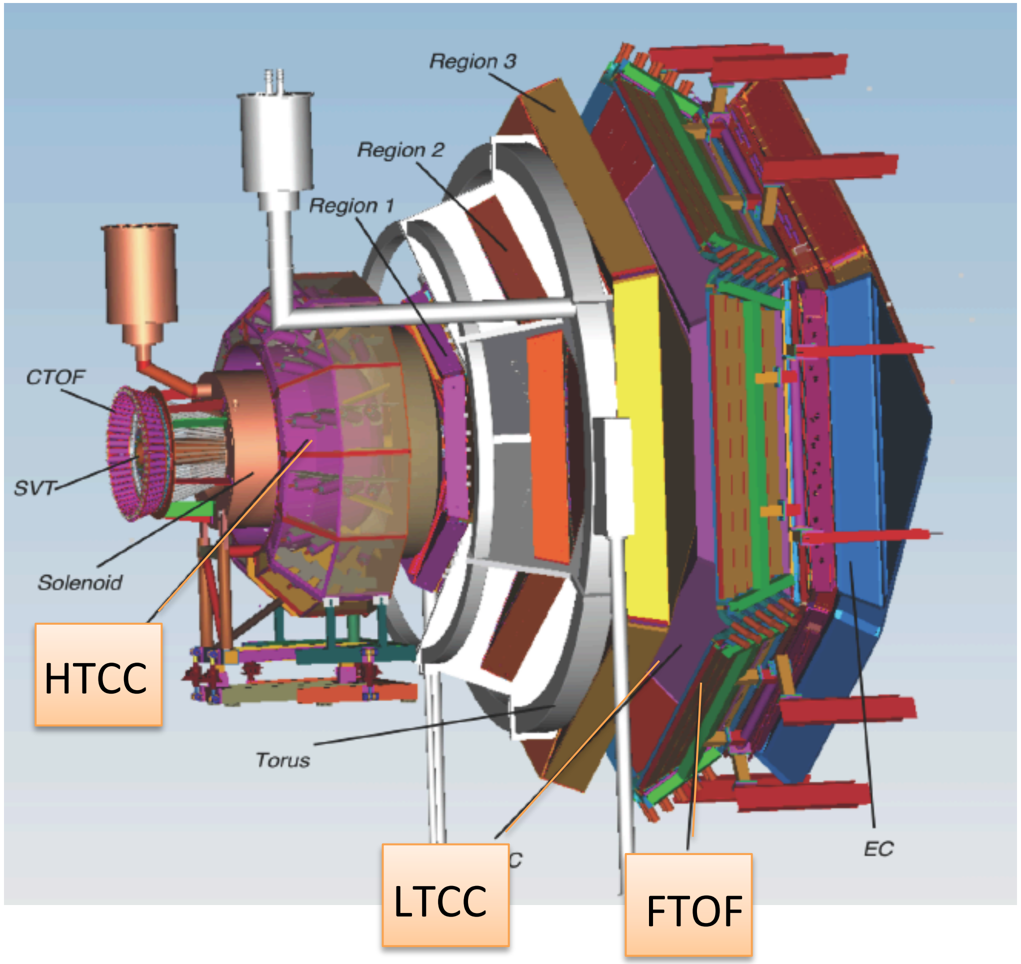


Baseline PID @ CLAS12

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

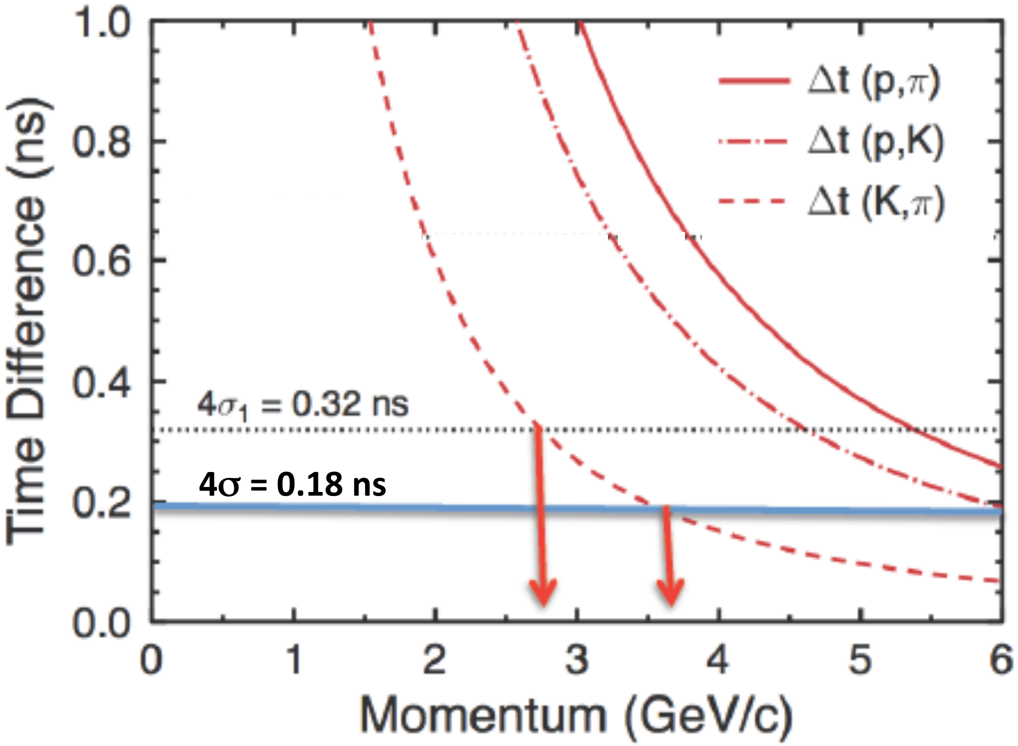


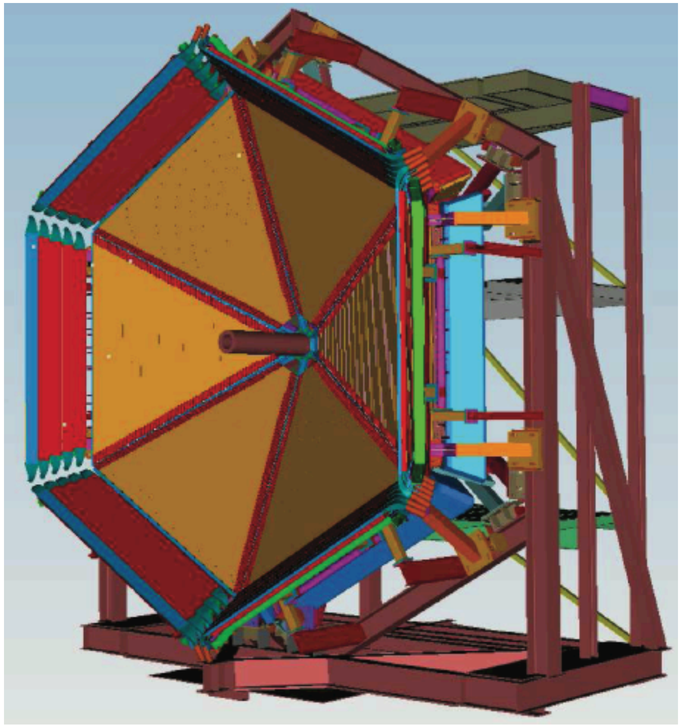
FTOF @ CLAS12

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





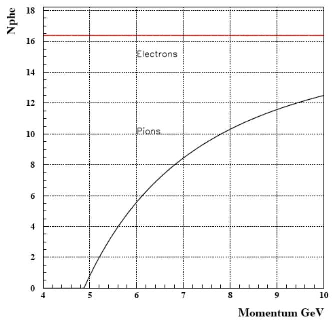
Time separation at 650 cm from IP:

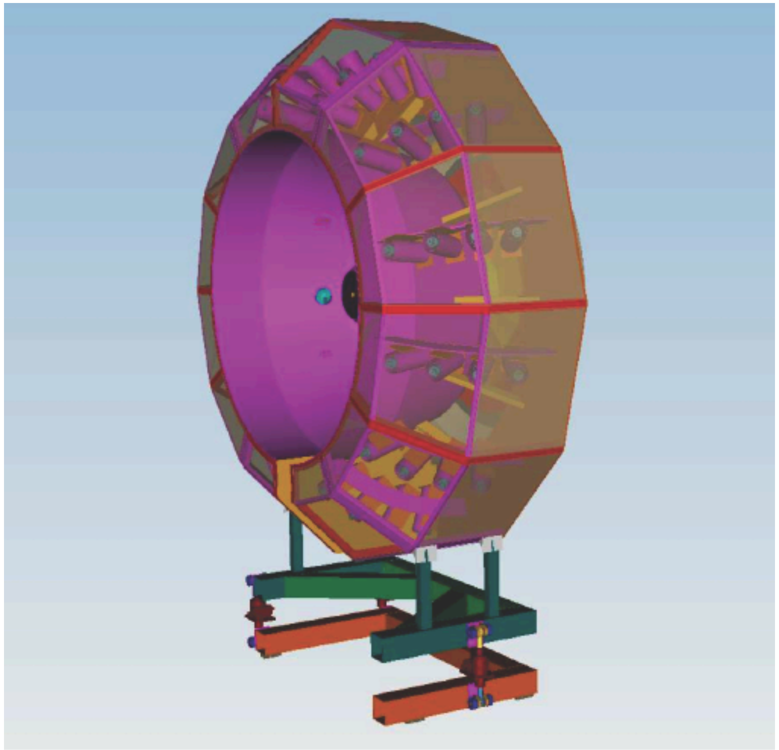
Up to 2.8 GeV/c (θ = 36 degrees)
Up to 3.6 GeV/c (θ = 5 degrees)

for 90 % kaon efficiency

HTCC @ CLAS12

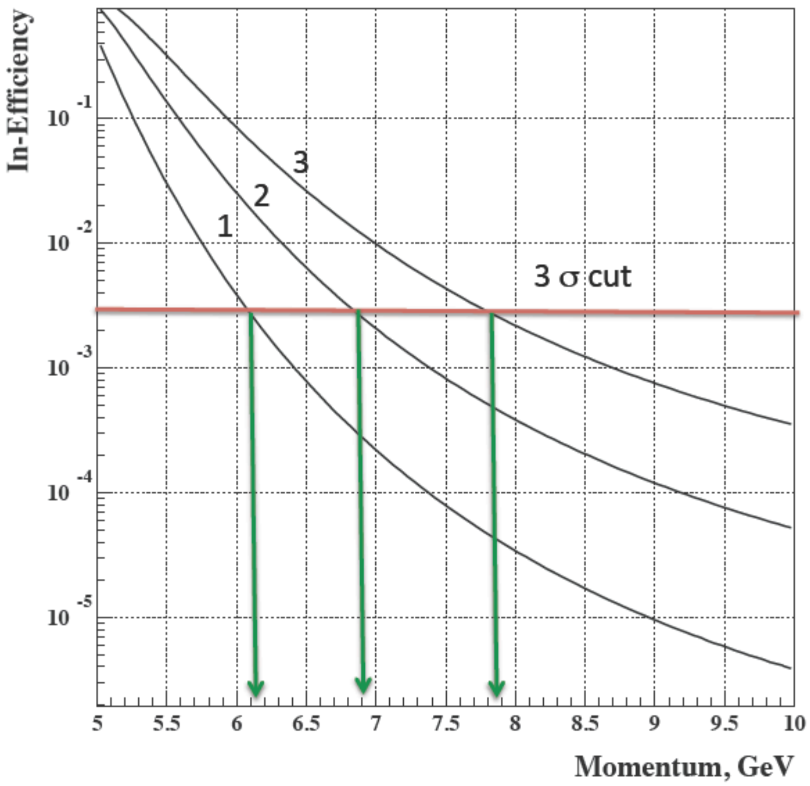
New detector for electrons ID:





CO_2 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)

~ % level around 6 GeV/c

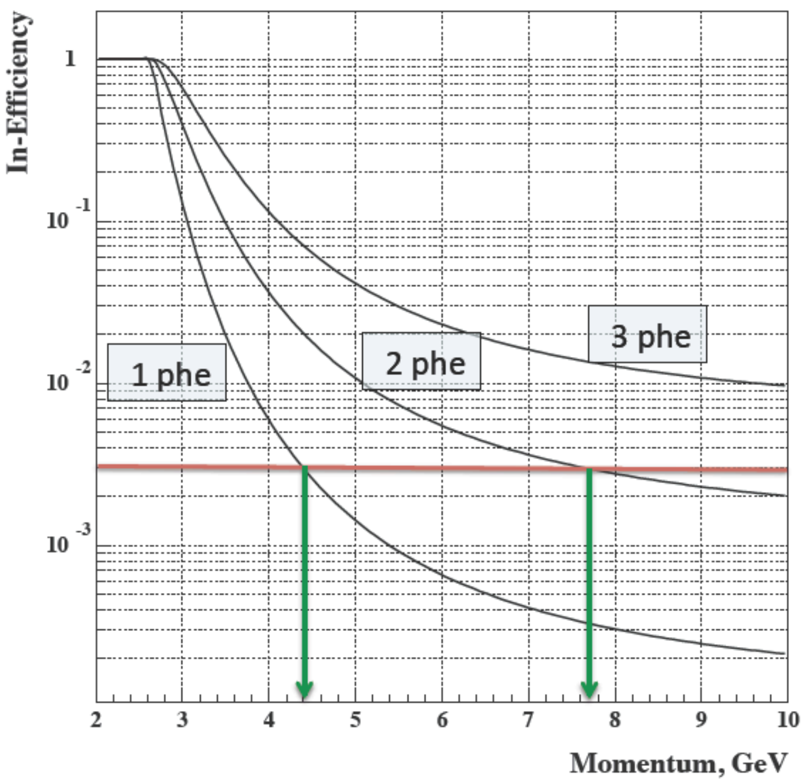
~ few per mil above 7 GeV/c

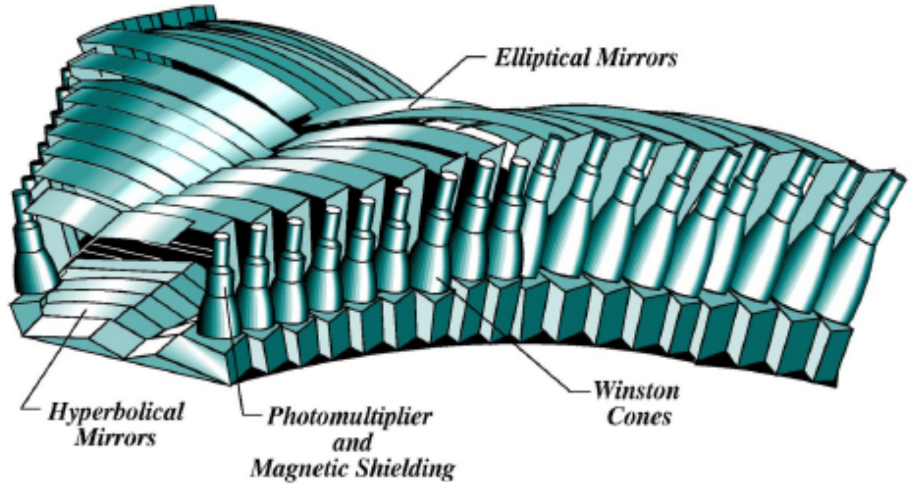
LTCC @ CLAS12

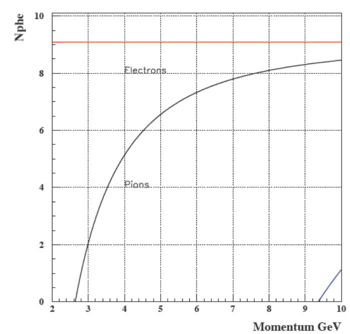
Derived from CLAS for pion ID:

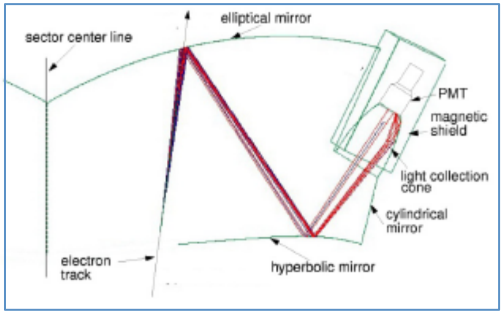
C_4F_{10} radiator
Complicated design with irregular response
Limited ϕ acceptance

Expected number of photoelectrons ~ 9









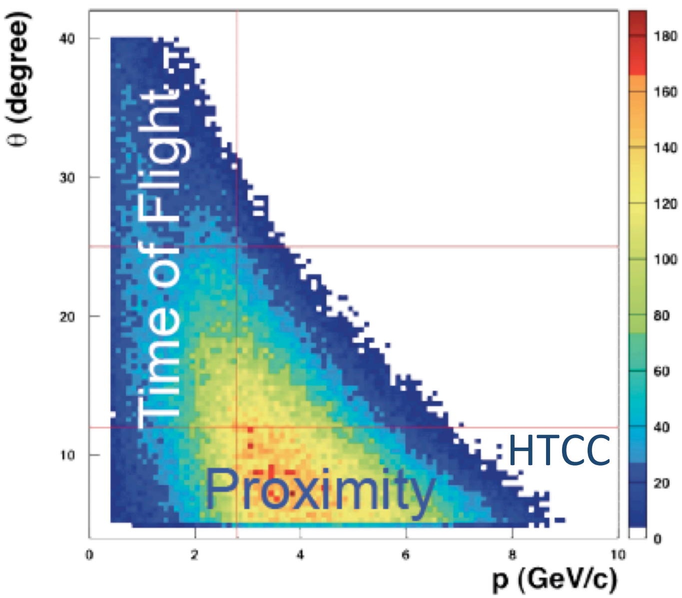
Pions in-efficiency for minimum p.e. number:

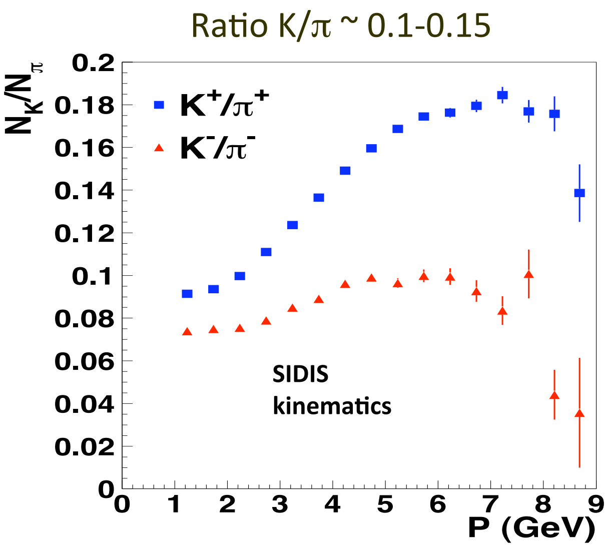
100 % below 2.7 GeV/c (Cherenkov threshold)

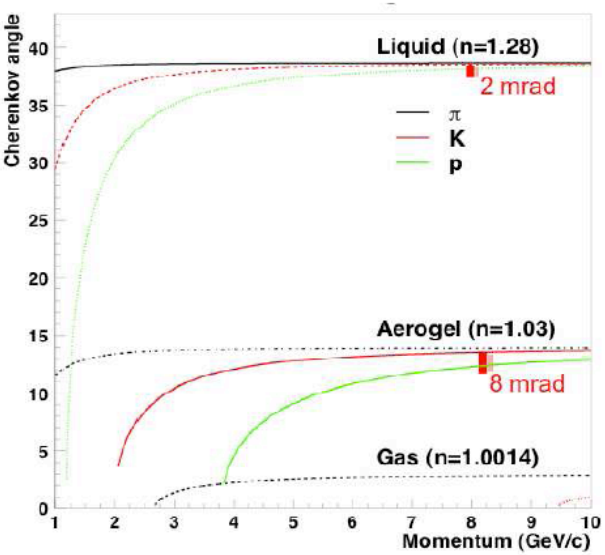
~ 10 % up to 5 GeV/c

~ % level above 5 GeV/c

CLAS12 Momentum Range



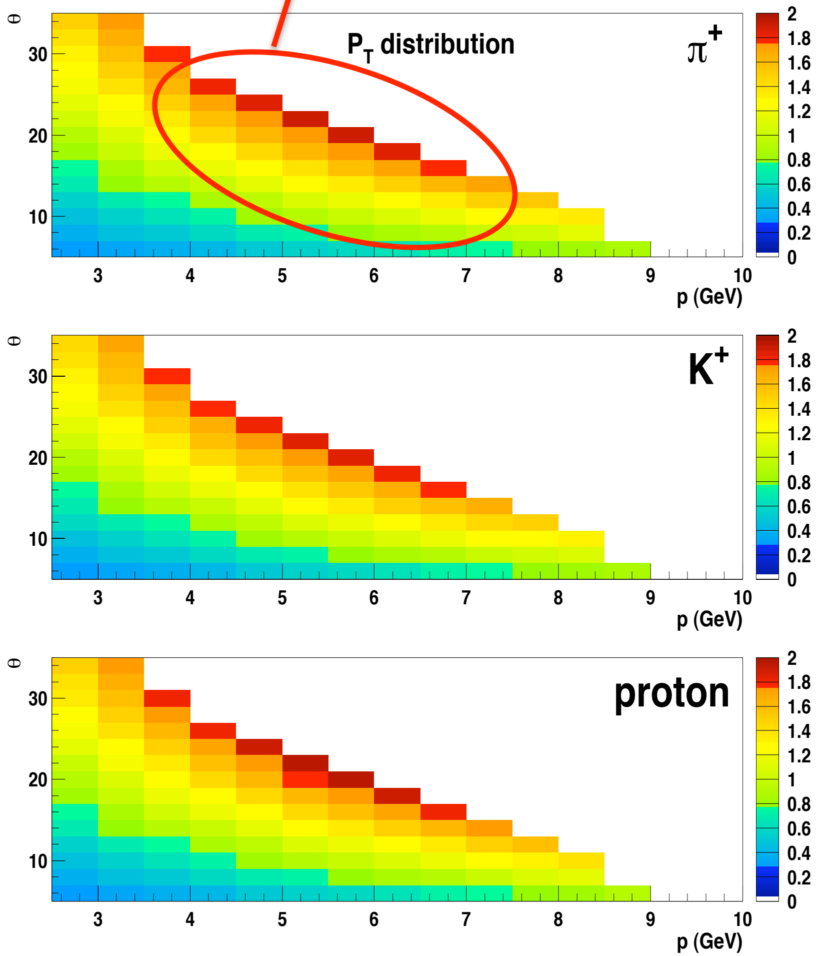




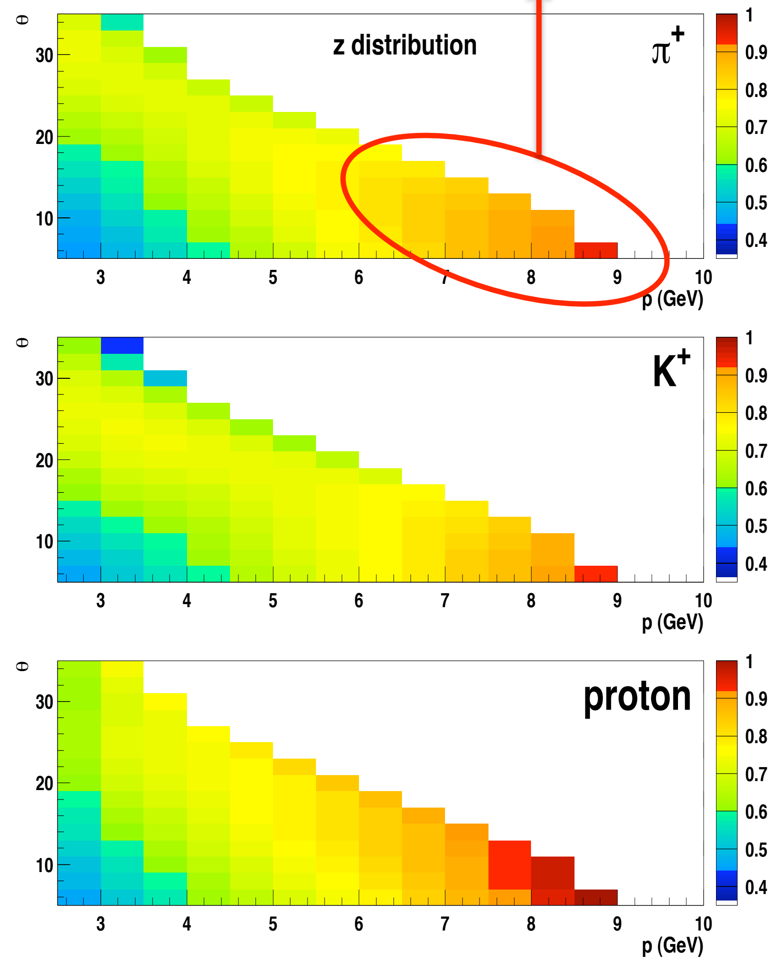
- **Aerogel** mandatory to separate hadrons in the 3-8 GeV/c momentum range with the required large rejection factors
  - → collection of **visible Cherenkov light**
  - → use of **PMTs**
- **Challenging project,** need **to** minimize detector area covered with expensive photodetectors

SIDIS Kinematics @ CLAS12

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

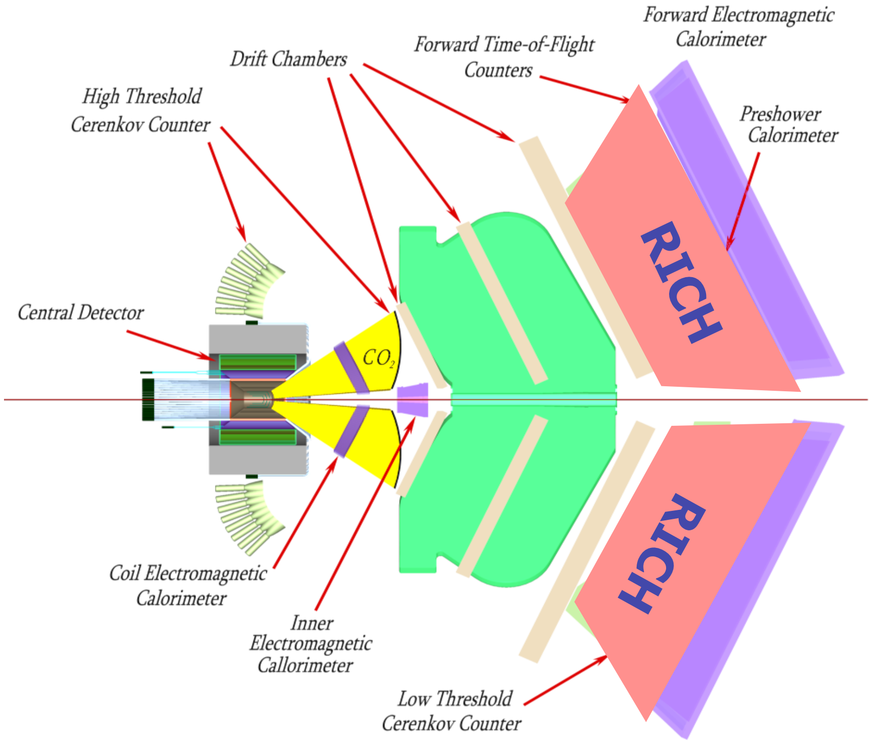


High Momentum region important as transient to hard semi-exclusive region



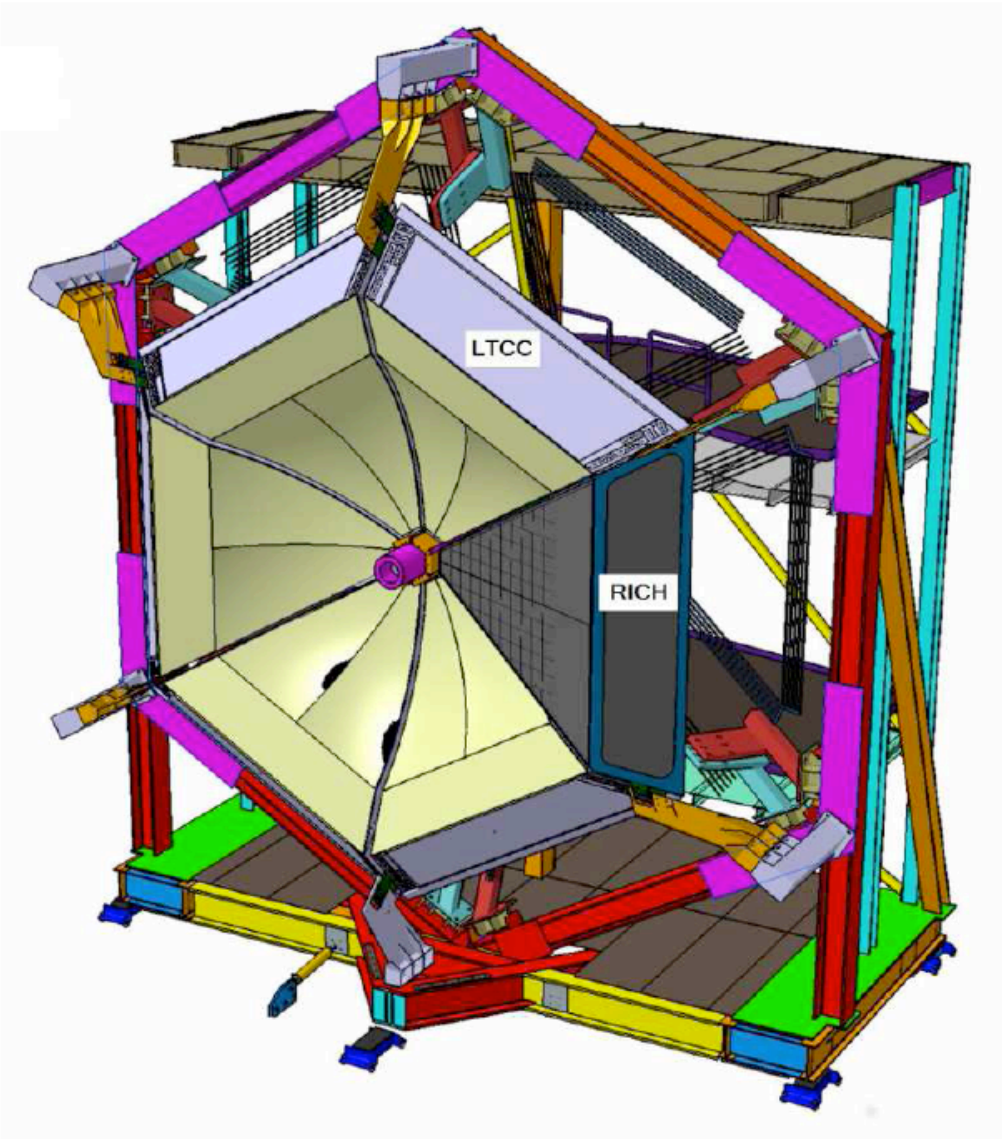
The CLAS12 RICH

RICH goal: **π/K/p separation of ~4 σ up to 8 GeV/c and 25 degrees**
for a pion rejection factor ~ **1:500**



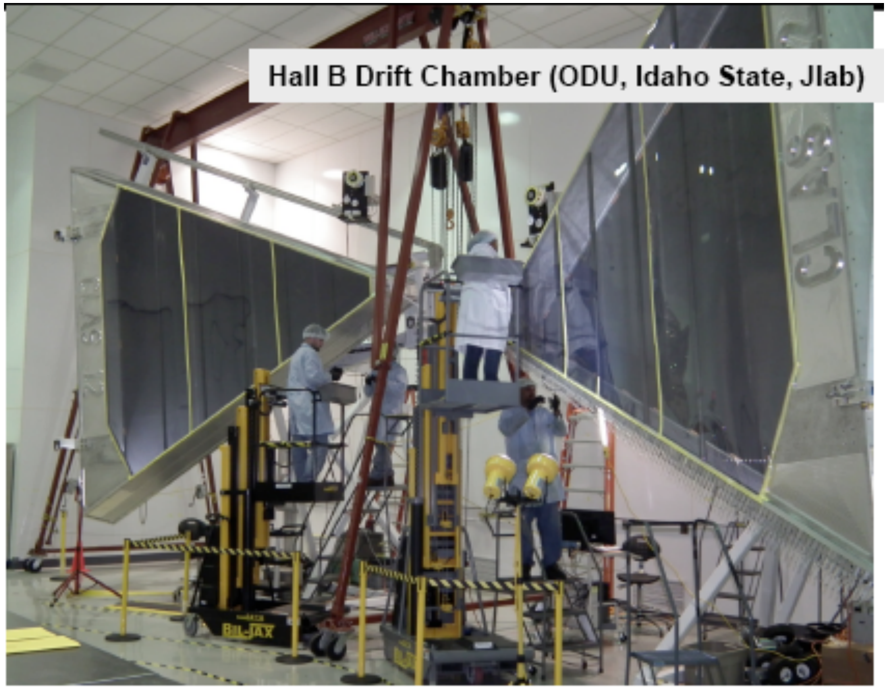
INSTITUTIONS
Jefferson Lab (Newport News, USA)
INFN (Italy) Bari, Ferrara, Genova, L.Frascati, Roma/ISS
Argonne National Lab (Argonne, USA)
Duquesne University (Pittsburgh, USA)
Glasgow University (Glasgow, UK)
J. Gutenberg Universitat Mainz (Mainz, Germany)
Kyungpook National University, (Daegu, Korea)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

RICH Base Configuration



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

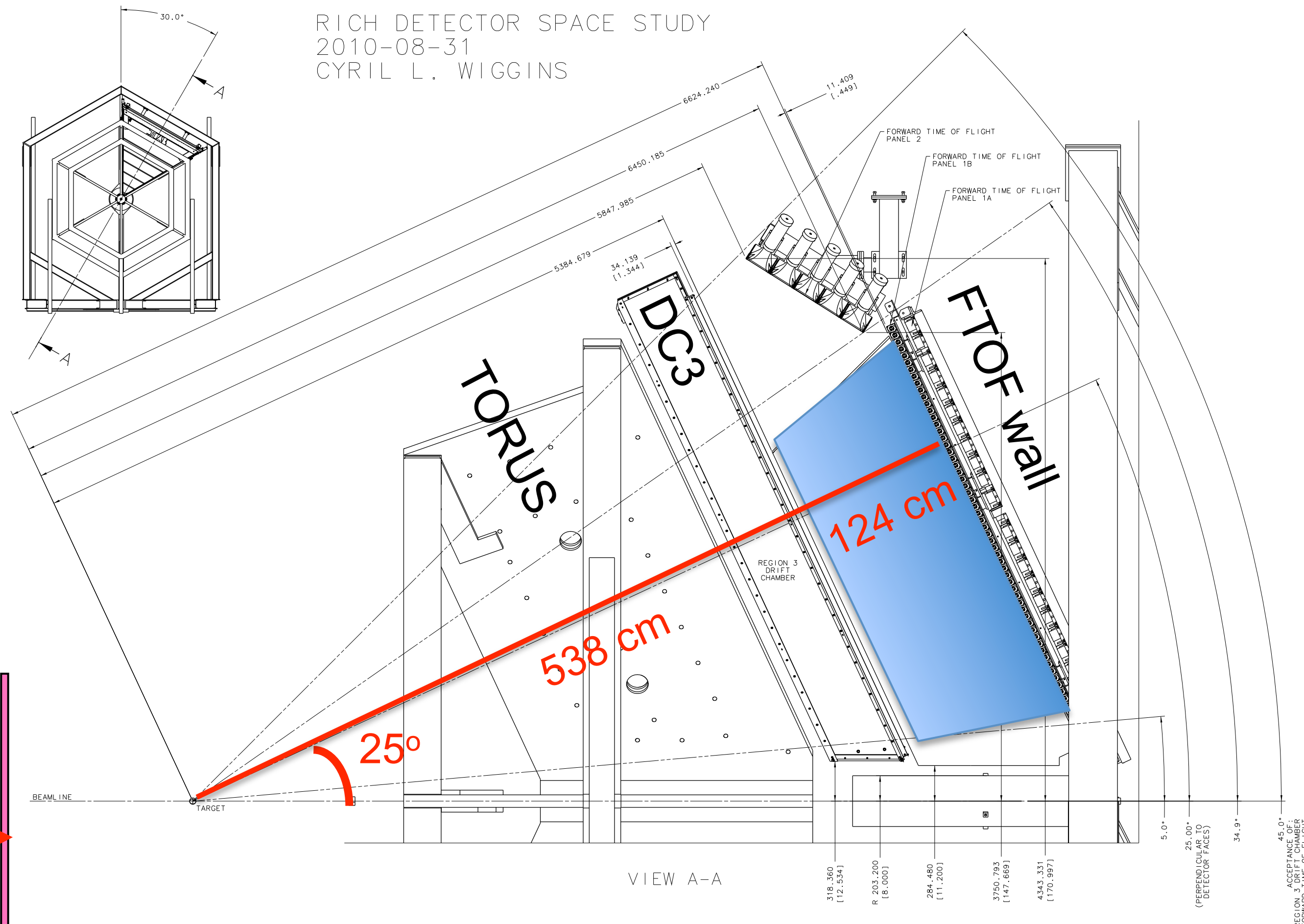
2nd++ sector for transverse target
(left-right symmetry and statistics)



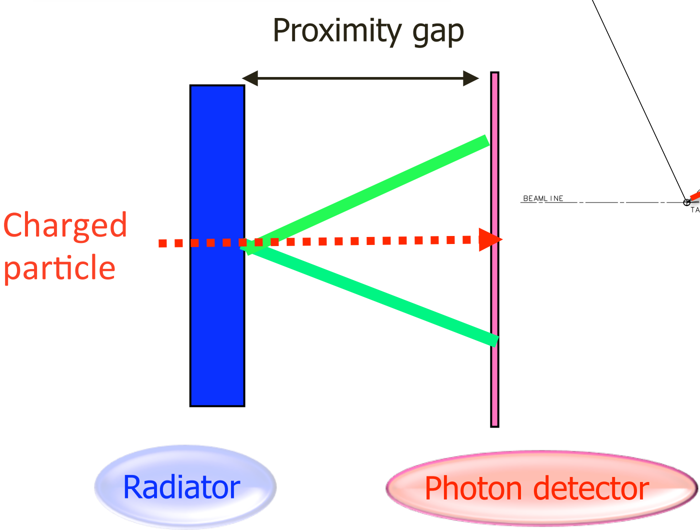
CLAS12 Geometry Constraints

Base Numbers

- 5 m from IP
- ~ 1 m gap
- Several m^2 surface

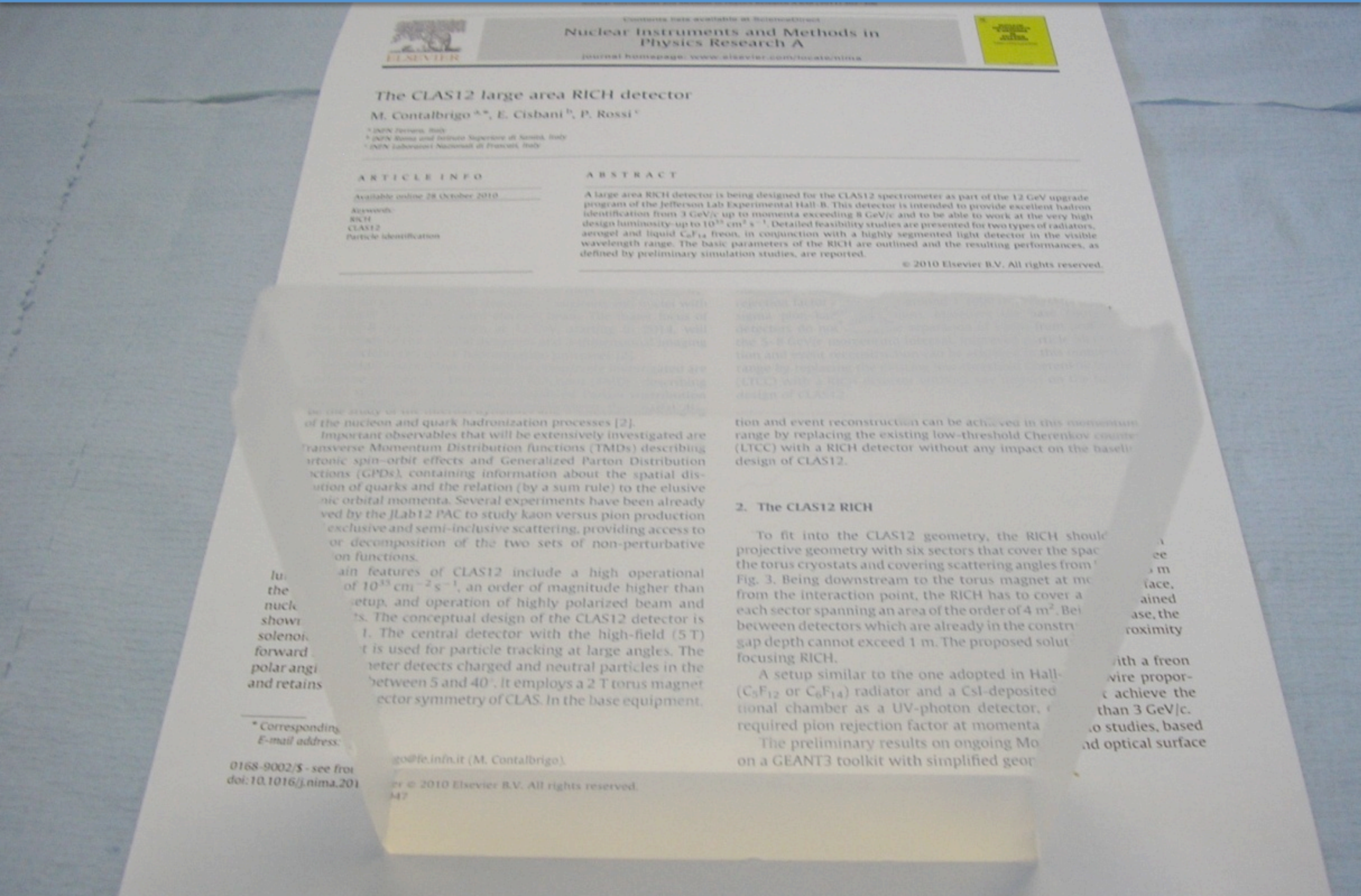


Proximity RICH



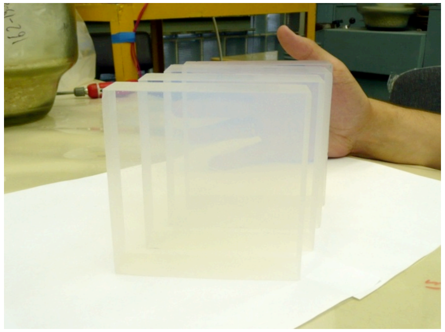
Radiator

Aerogel Radiator

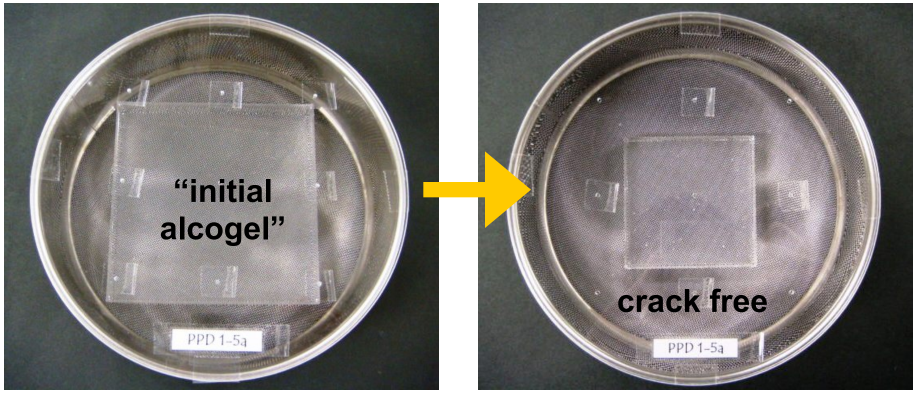


Aerogel Transmission Length

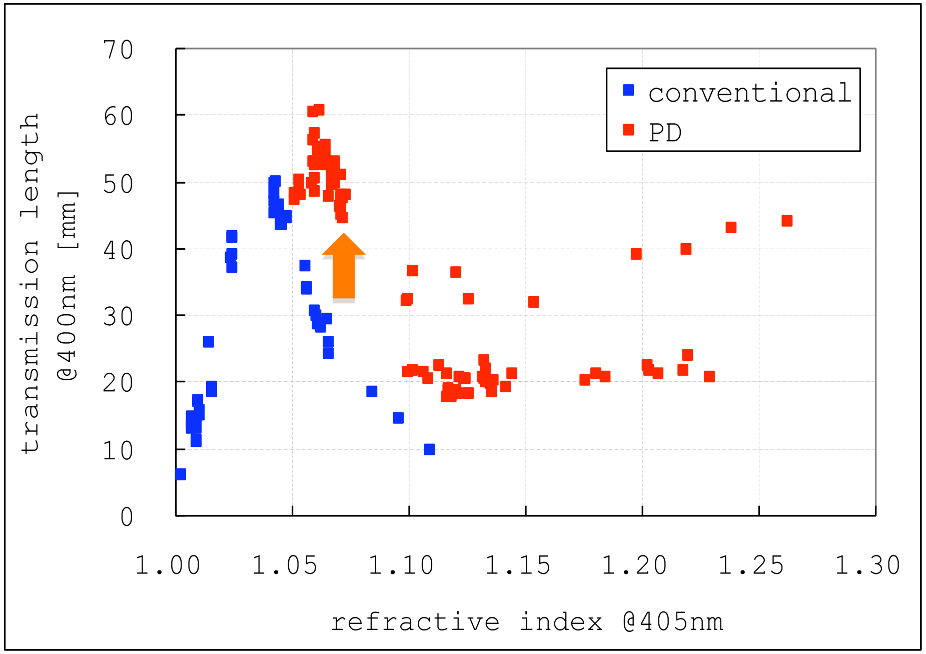
"Pinhole drying (PD)" method:
artificially shrinks alcogel to obtain high index
Transparency doubled for n>1.05 aerogel



M. Tabata @ RICH 2010



pinhole drying process

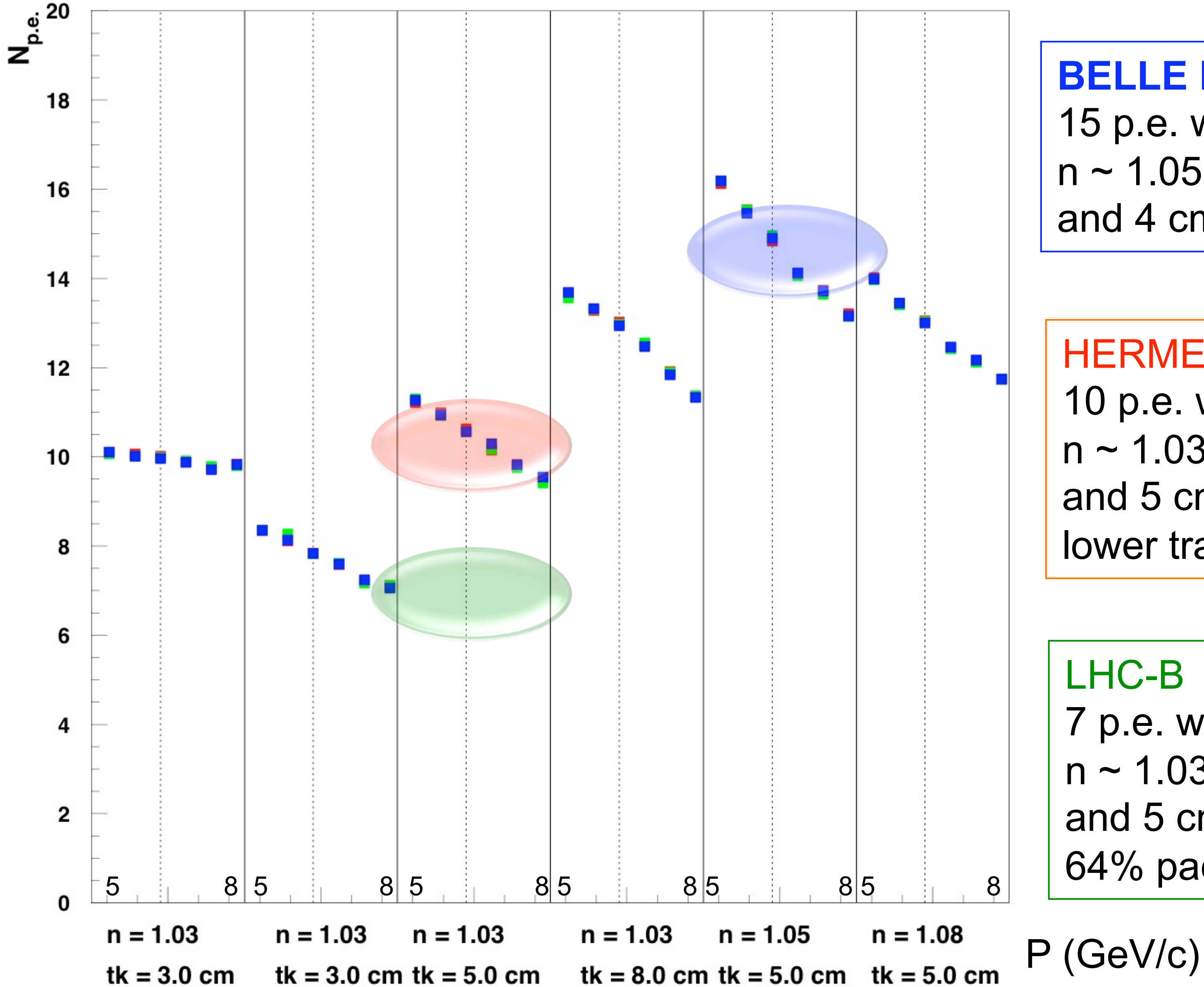


A.F. Danilyuk @ RICH 2010

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

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

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

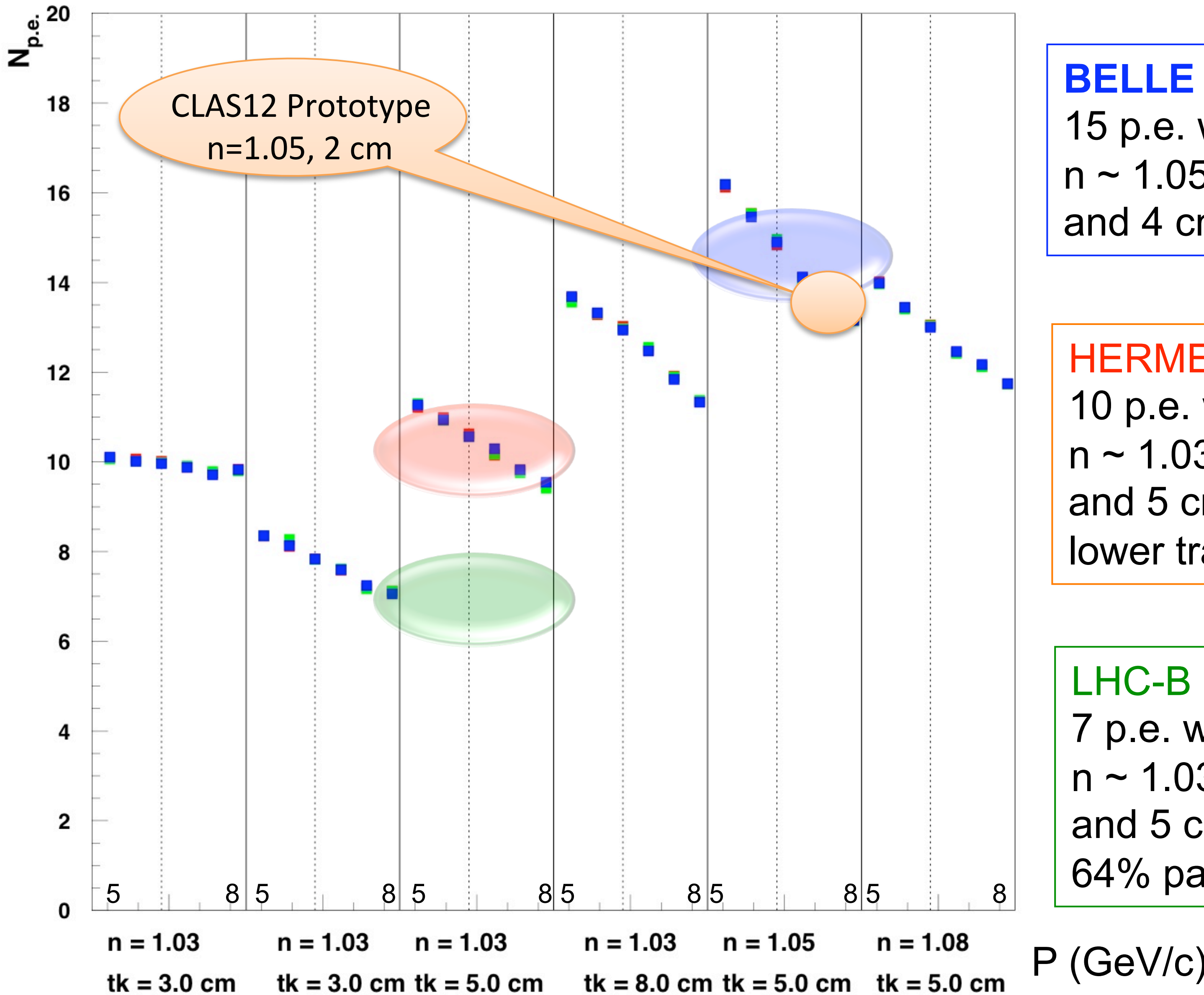


BELLE II test-bench
15 p.e. with aerogel of n ~ 1.05 refractive index and 4 cm thickness

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)



BELLE II test-bench
15 p.e. with aerogel of
n ~ 1.05 refractive index
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LHC-B
7 p.e. with aerogel of
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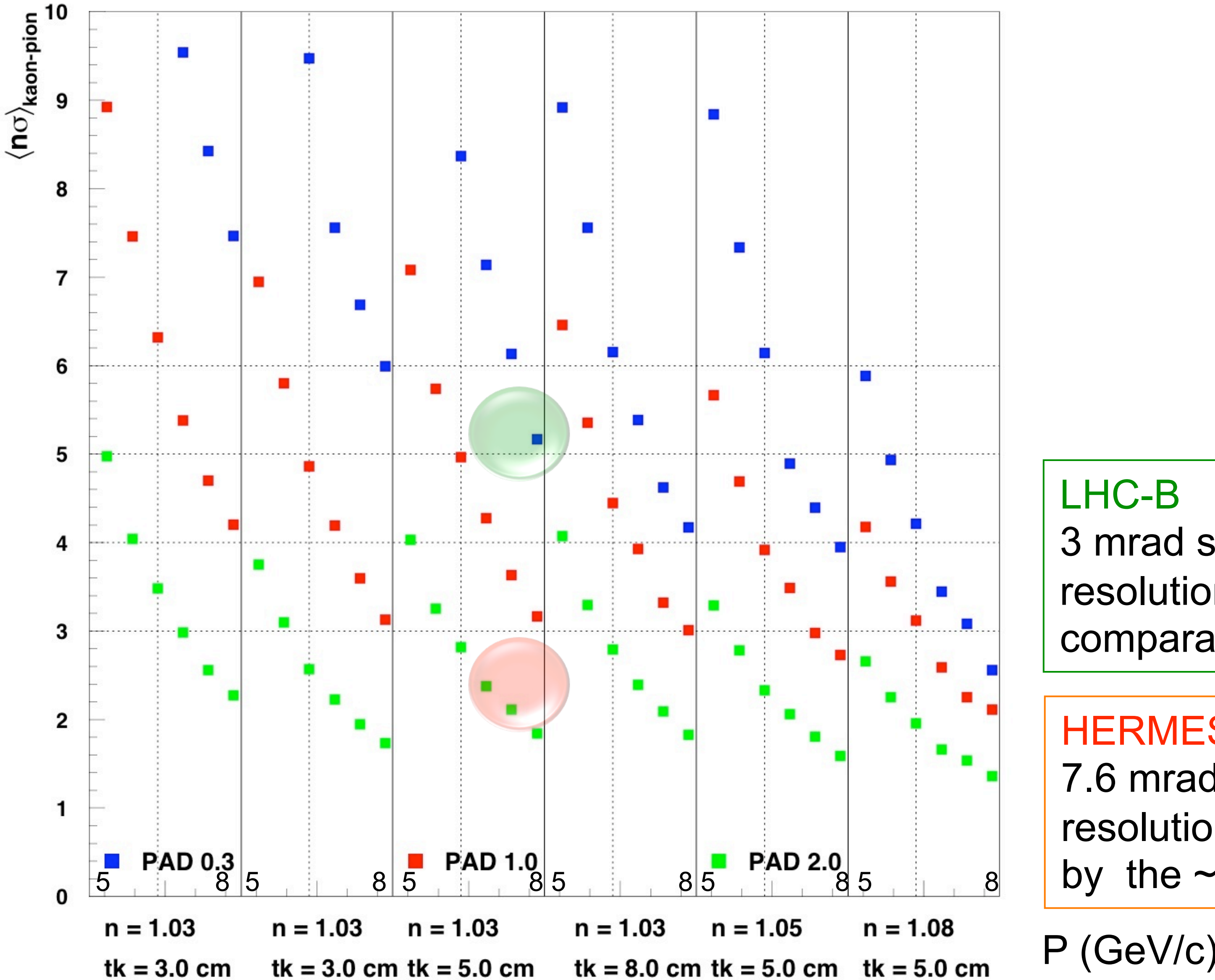
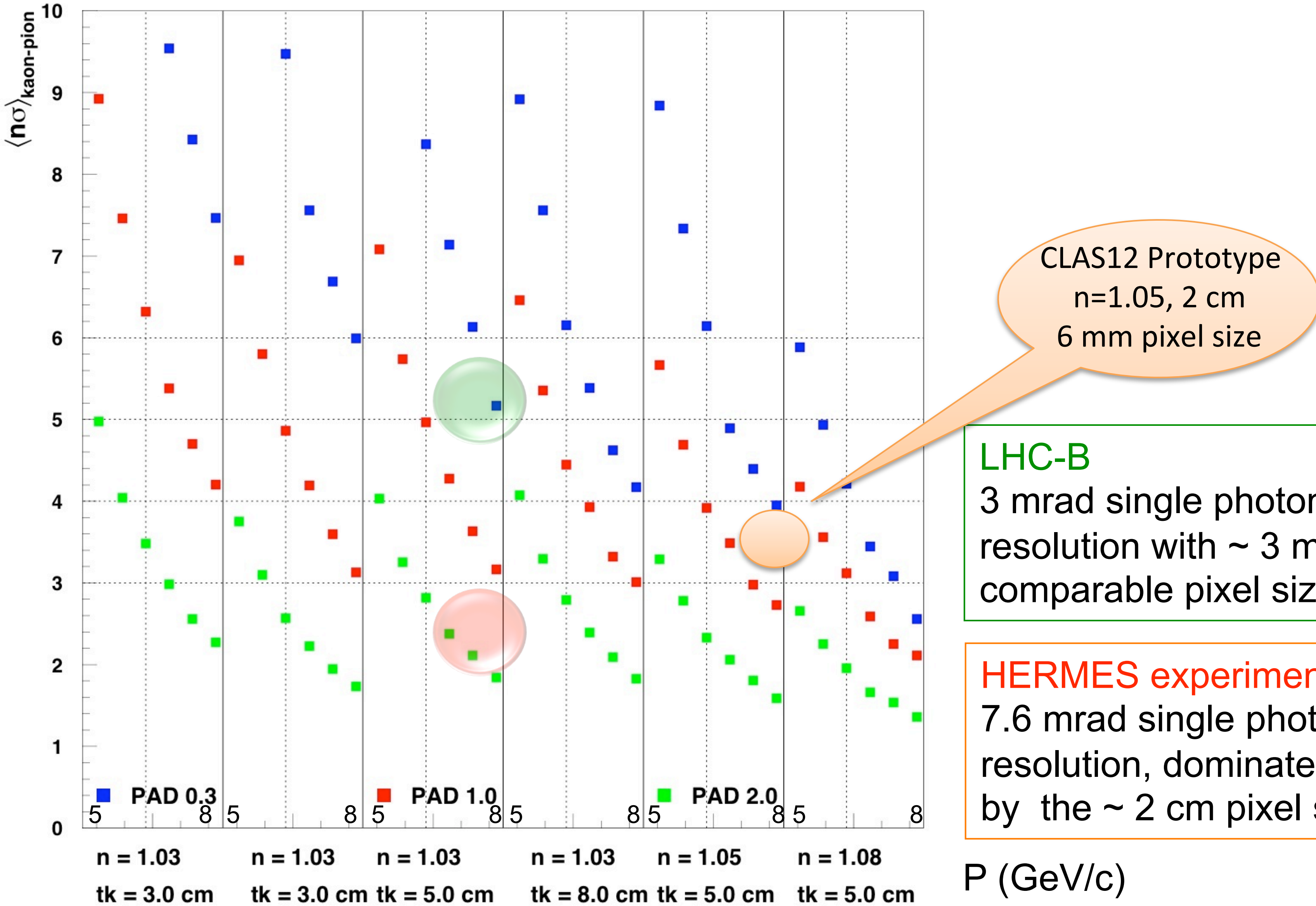
Mean π/K Separation (5-8 GeV/c)



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

Mean π/K Separation (5-8 GeV/c)



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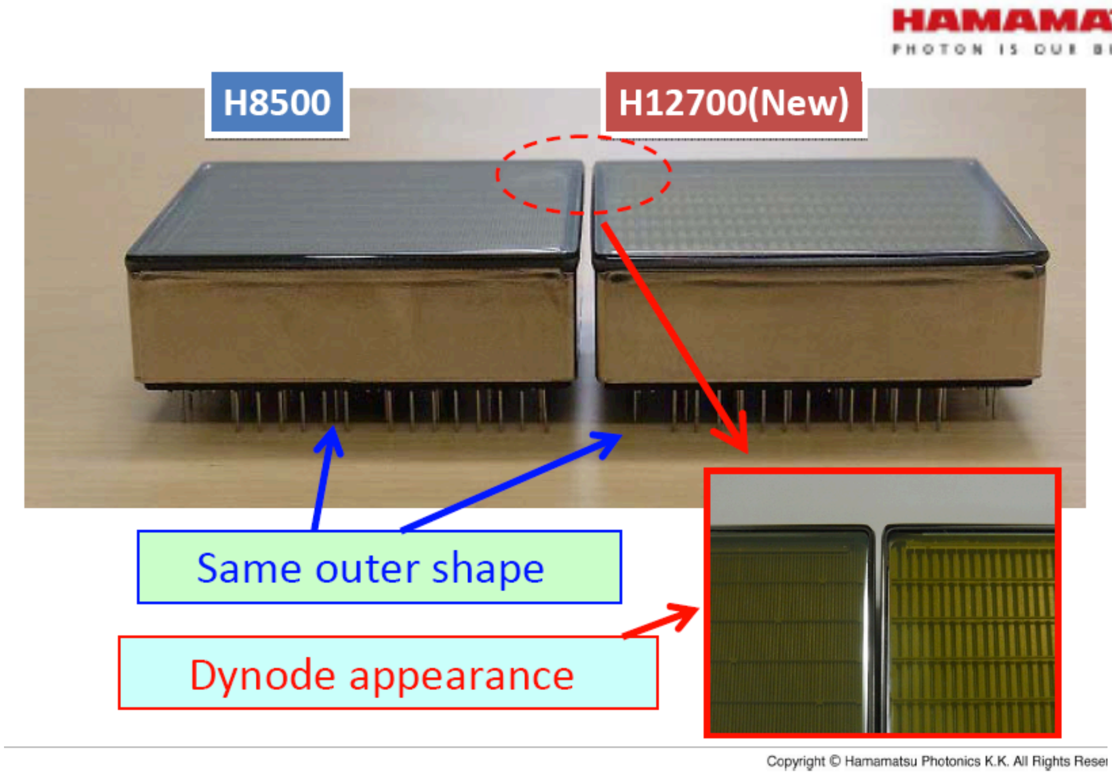
3 mrad single photon resolution with ~ 3 mm comparable pixel size

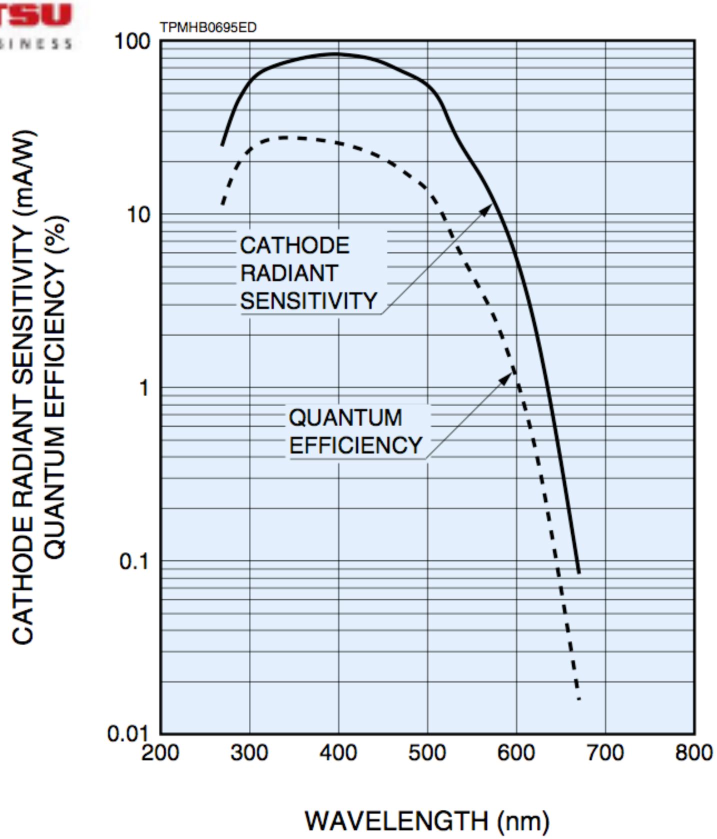
HERMES experiment
7.6 mrad single photon resolution, dominated by the ~ 2 cm pixel size

PhotoDetector

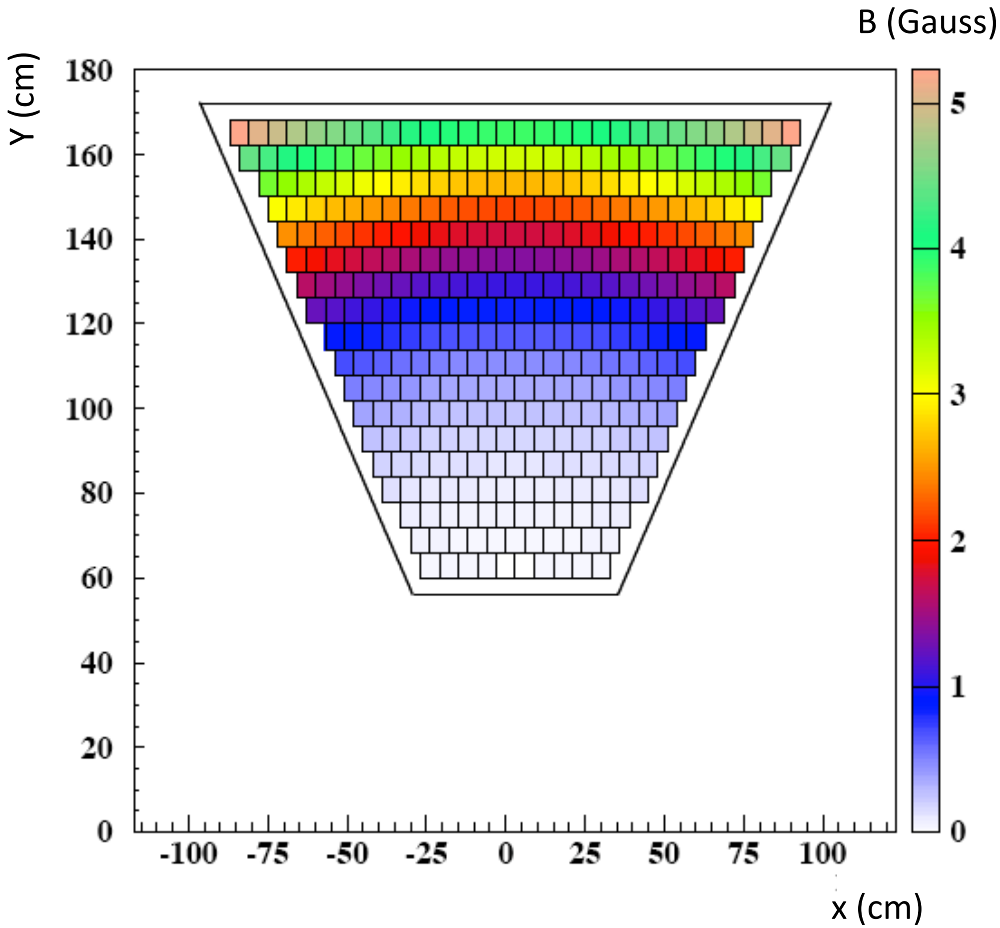
Photon Detectors: MA-PMT

Multi-Anode Photomultipliers: Large Area (5x5 cm^2)
Cost-Effective Devices (~2.3 k$ each)
High packing density (89 %)



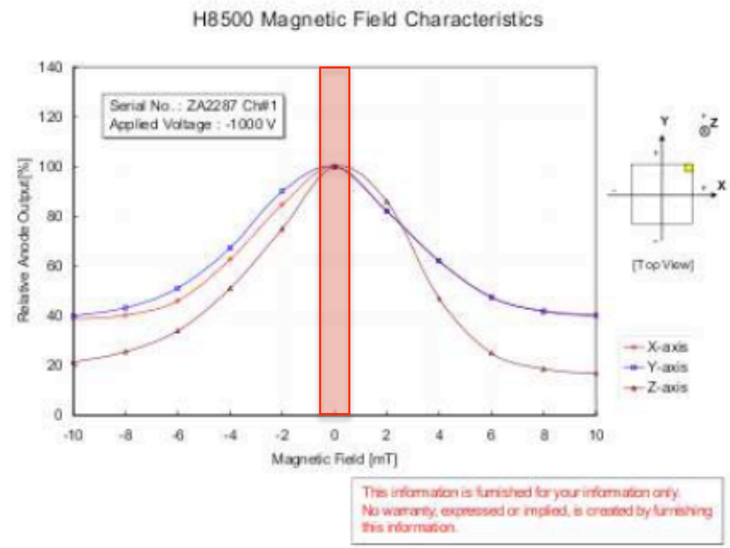


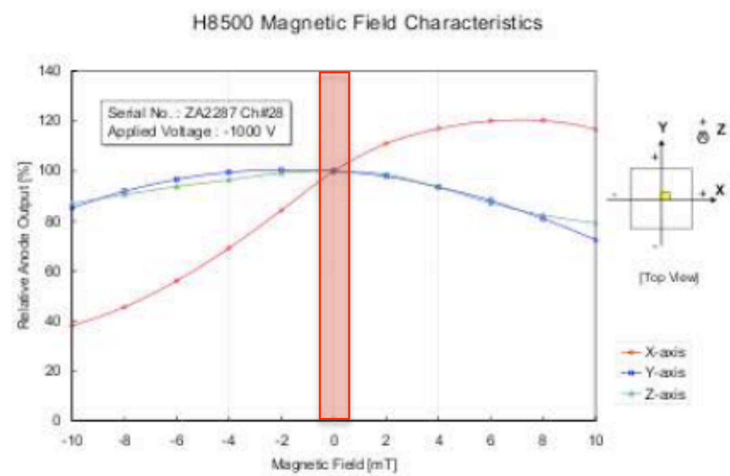
Magnetic Field



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

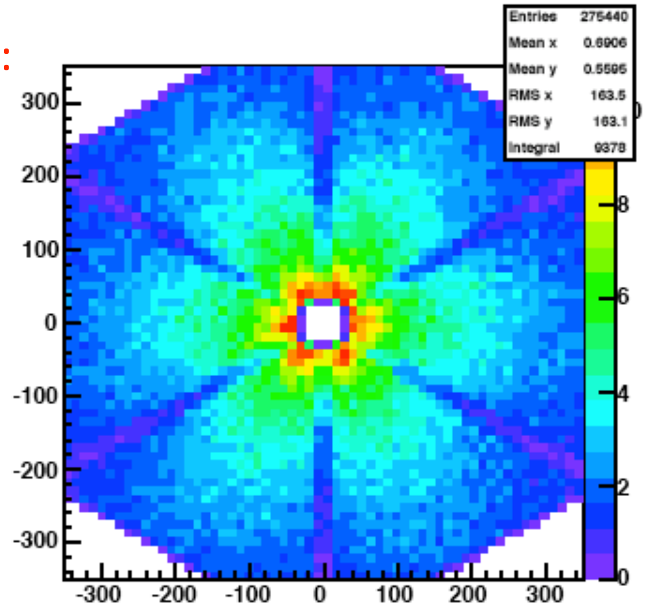
HAMAMATSU



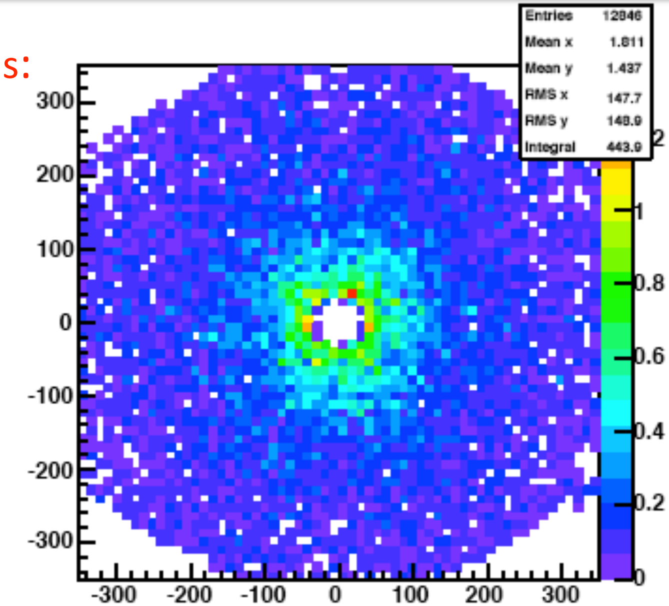


Radiation Damage

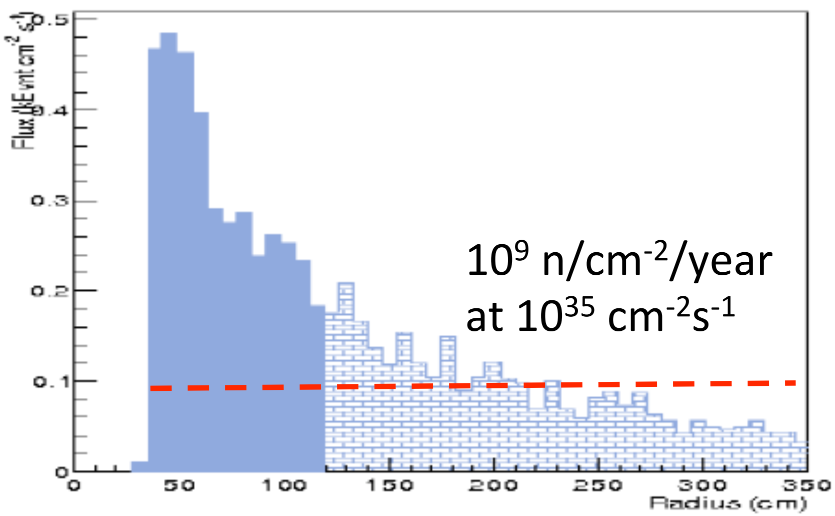
Gammas:

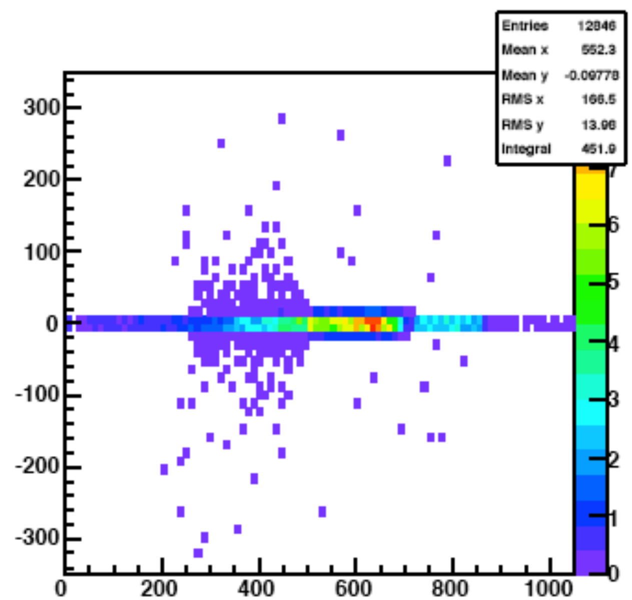


Neutrons:



Neutrons:



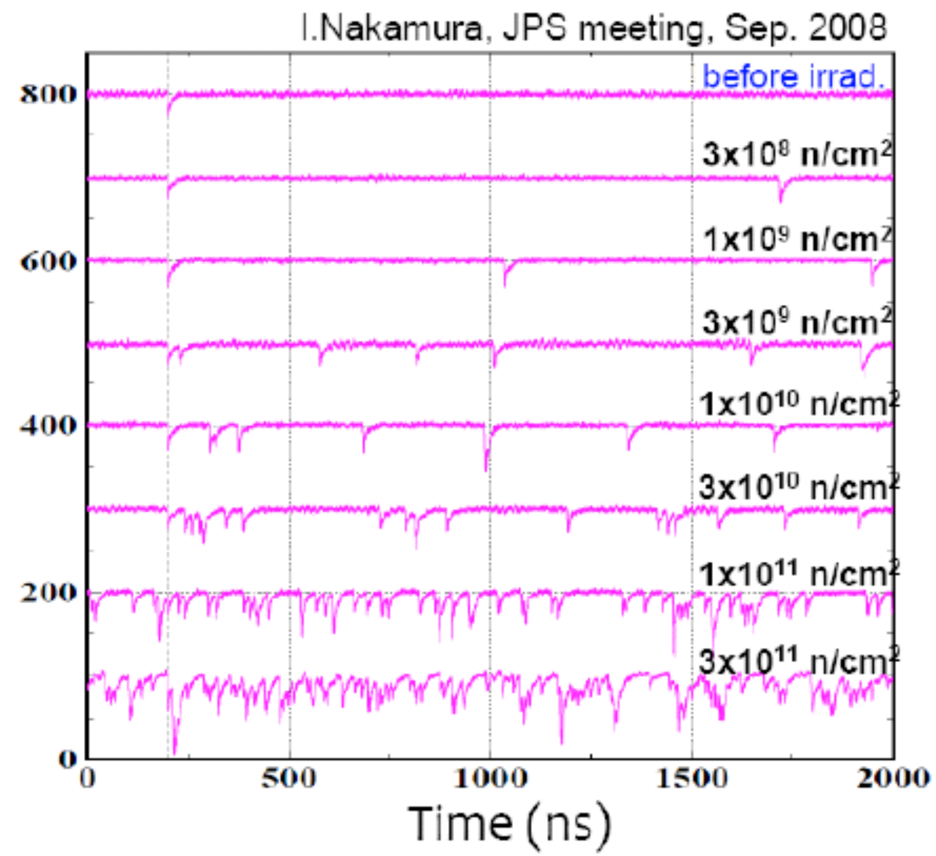


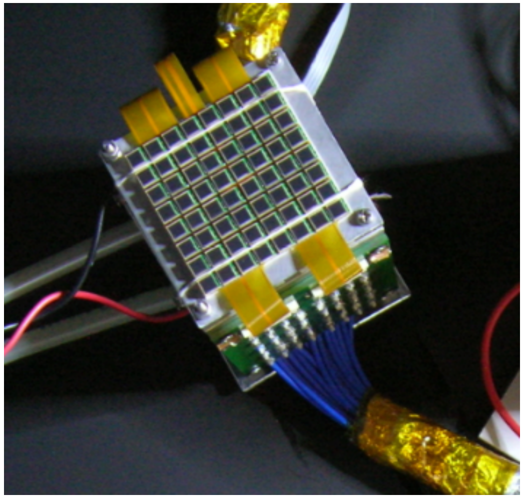
Photon Detectors: SiPM

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





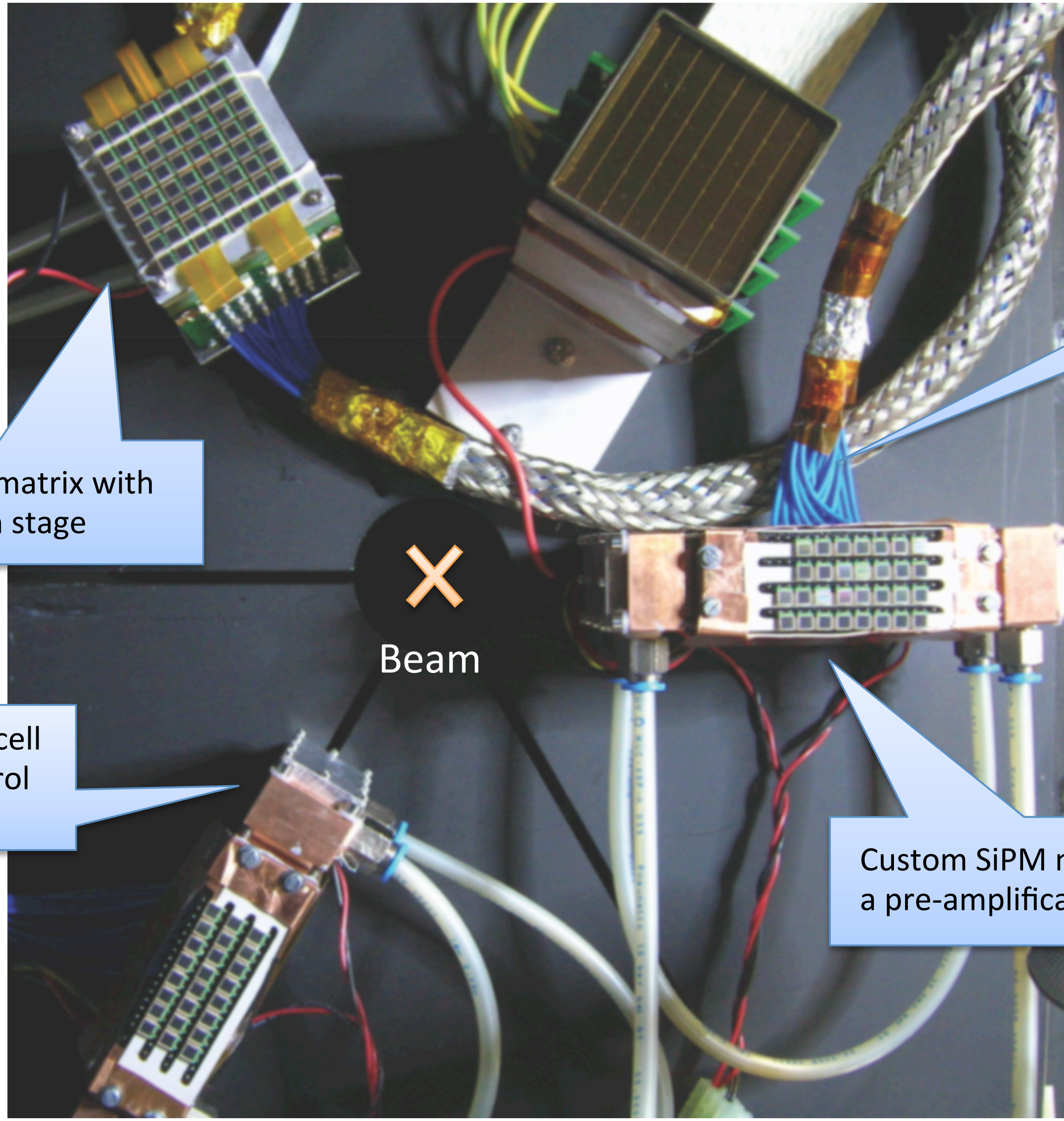
Fluence at CLAS12 allows the use of SiPM for future upgrades:

✓ fast develop in performances (dark count ~ 1 Mhz for 3x3 mm^2 devices)

✓ fast reduction in price (already comparable with MA-PMTs over 1 m^2)

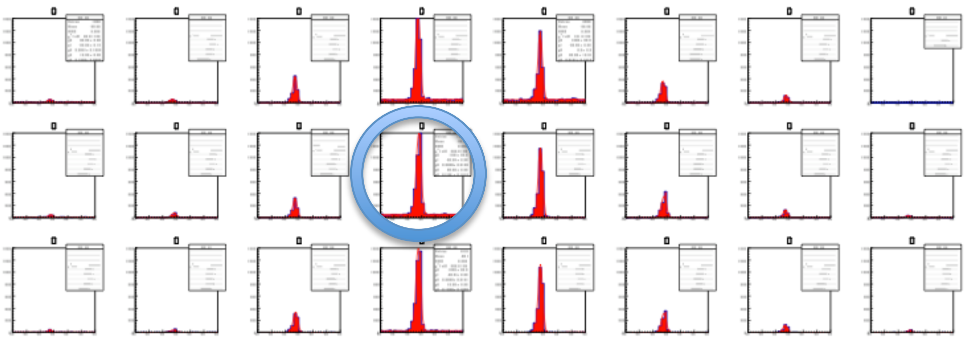
✗ require dedicated R&D for electronics and cooling

The SiPM Test Prototype



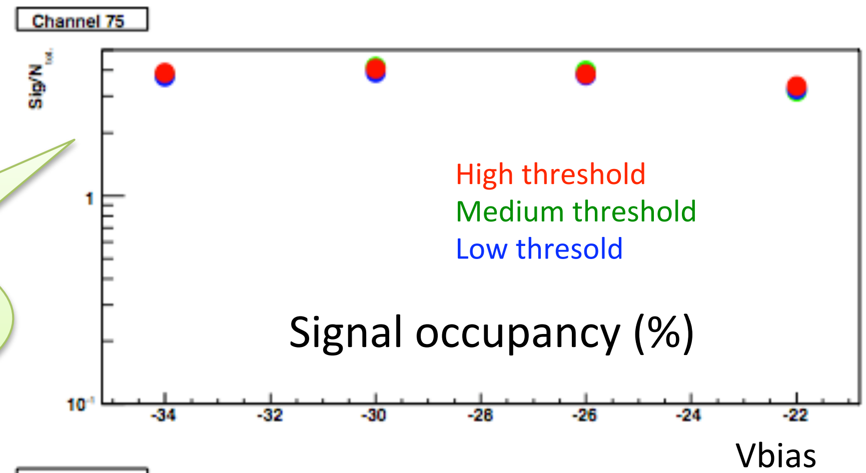
The Custom SiPM Matrix@-25°

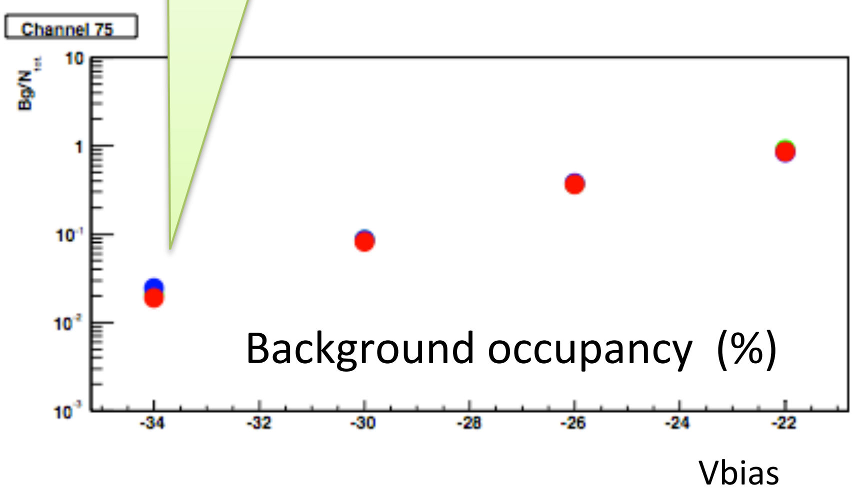
For a 12 cm radius Cherenkov cone and a 3 mm SiPM pixel, an occupancy of 4 % corresponds to about 24 p.e.

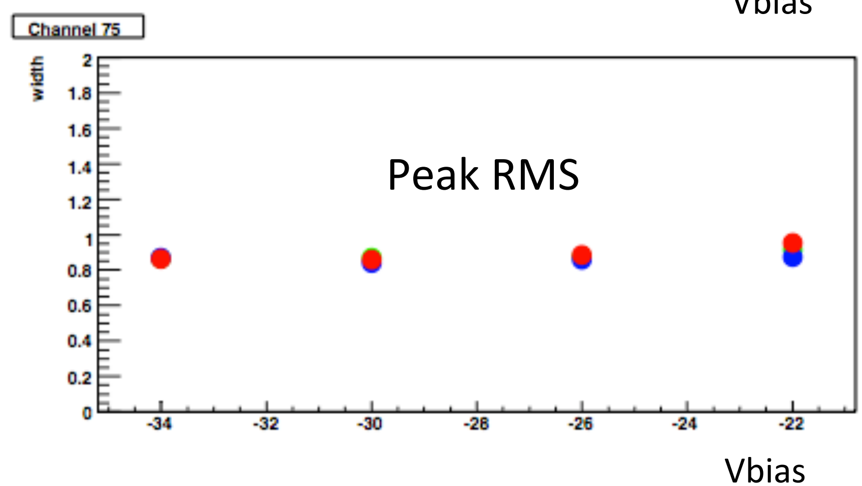


In a +/- 3 ns window
Comparable with H8500

Largely insensitivity to Vbias and discriminator threshold

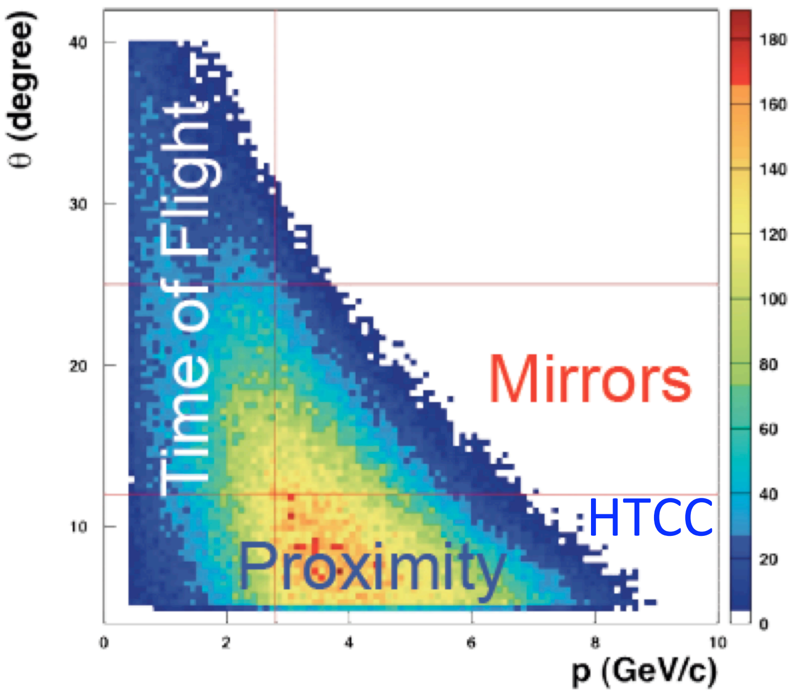


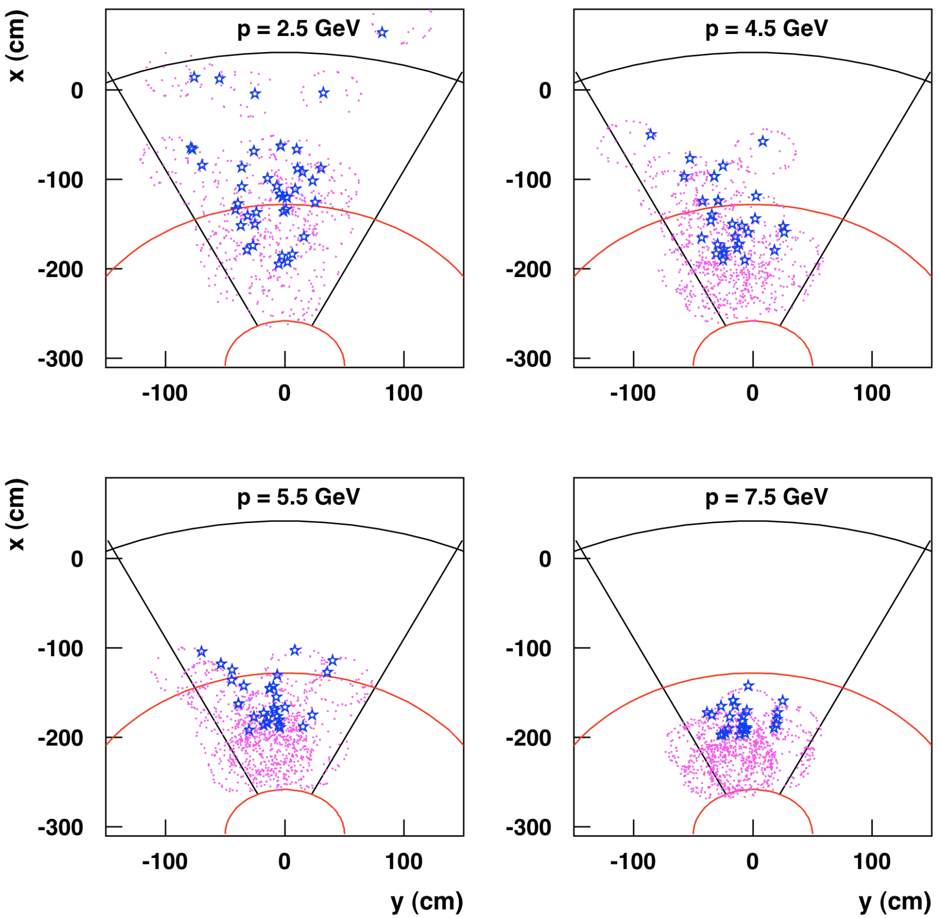




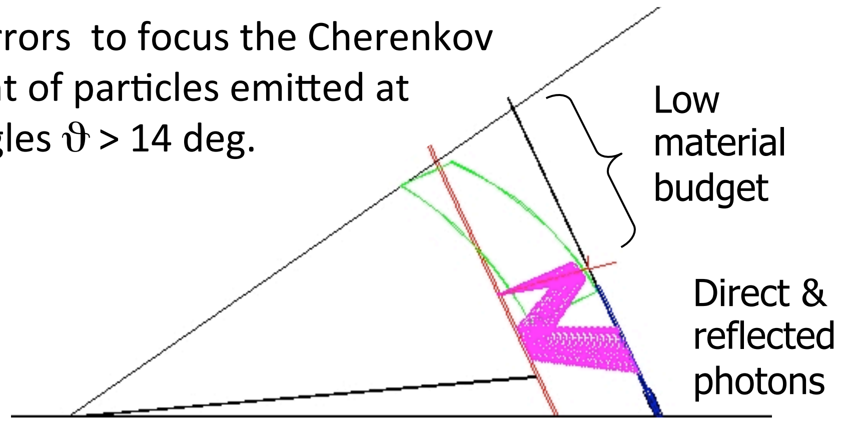
The Mirror System

The Mirror System





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

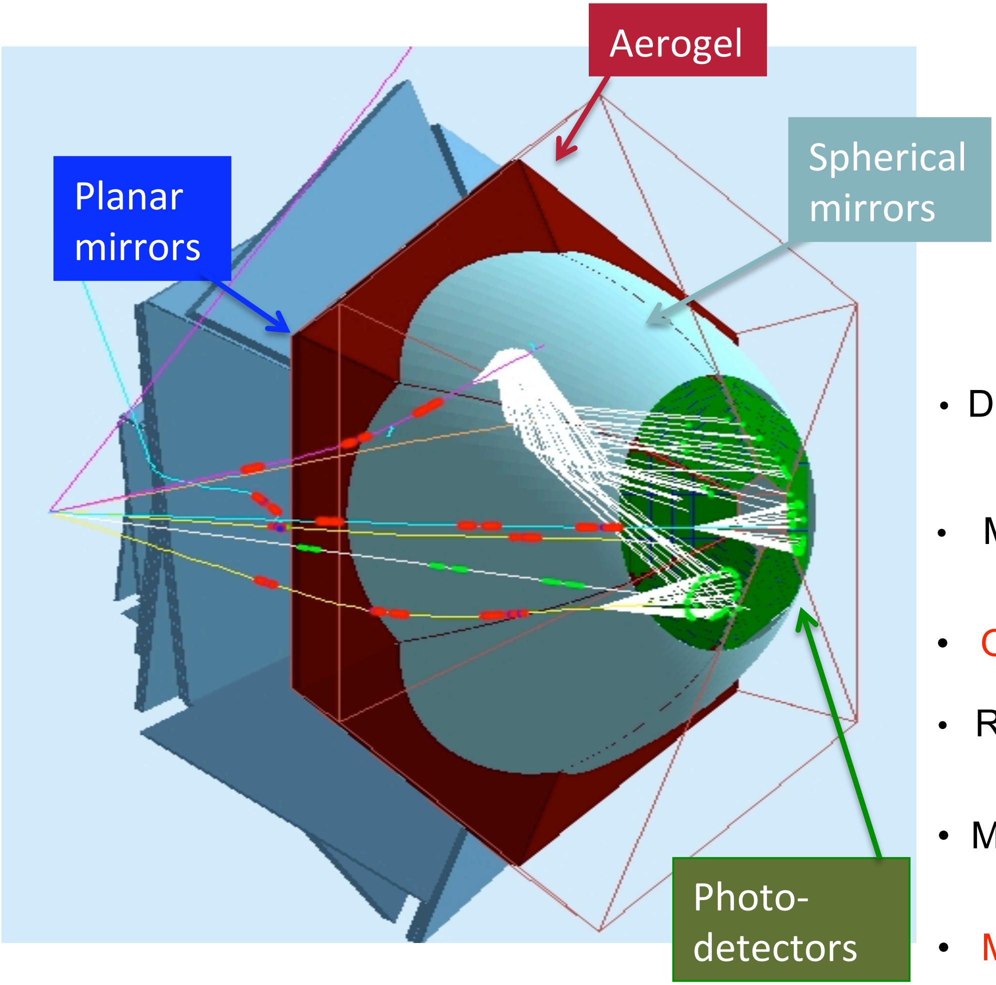


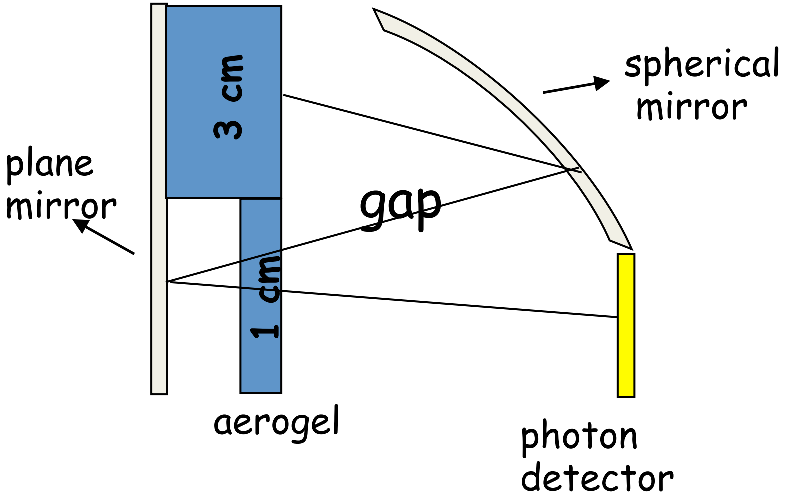
Goals:

- instrument only forward region
- reduce active area (~1 m^2/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)

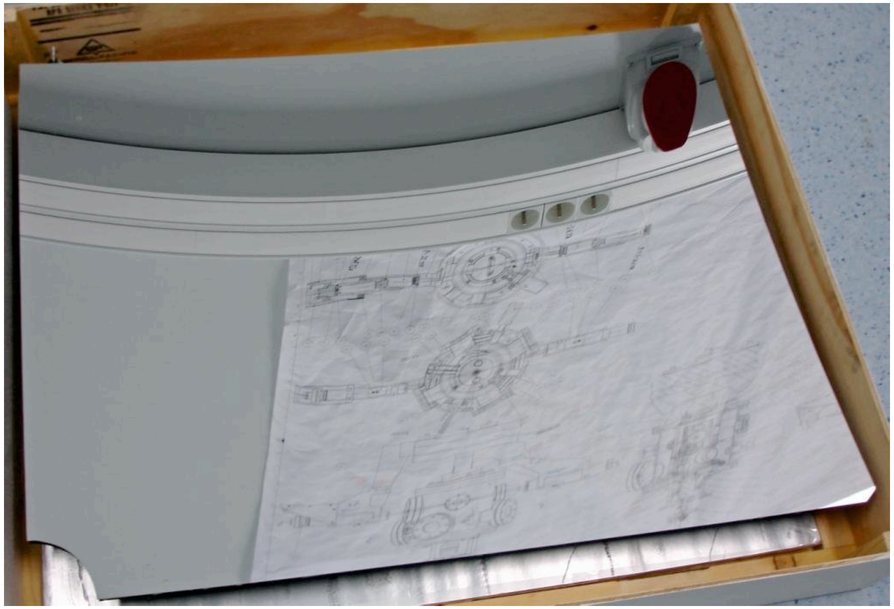
Mirror Technology

Metalized Carbon Fiber substrate

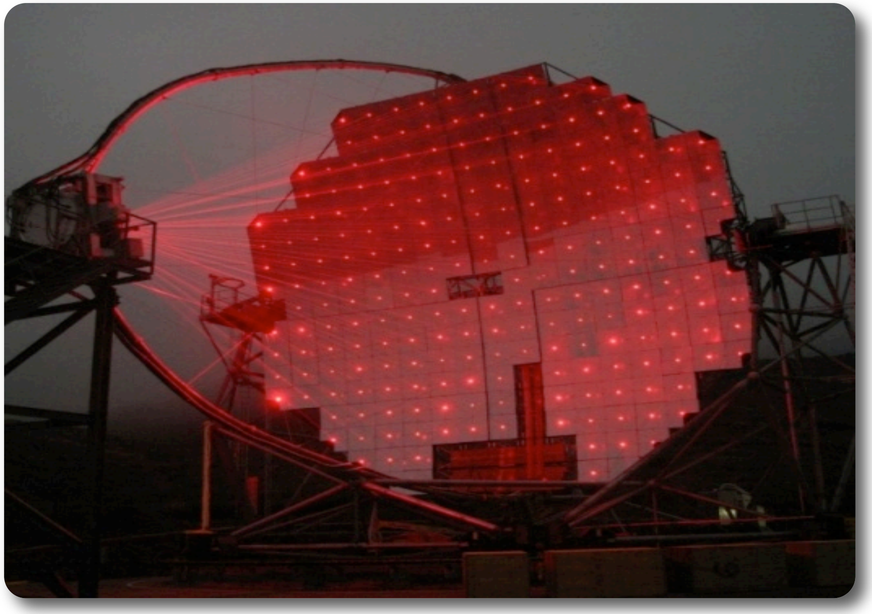
Self-supporting structure with
minimal material budget
(applications in physics experiments)

Thin glass skin embracing a honeycomb core

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



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

RICH outlook

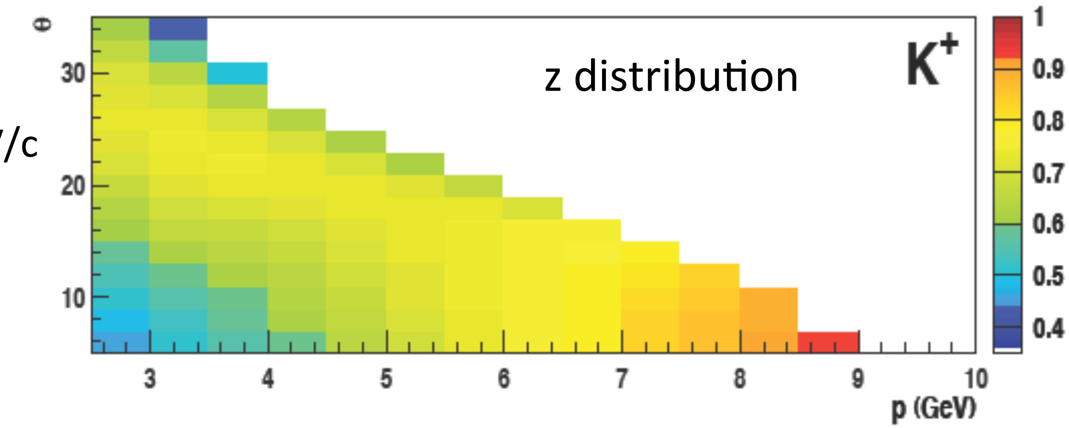
Summer 2013:

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

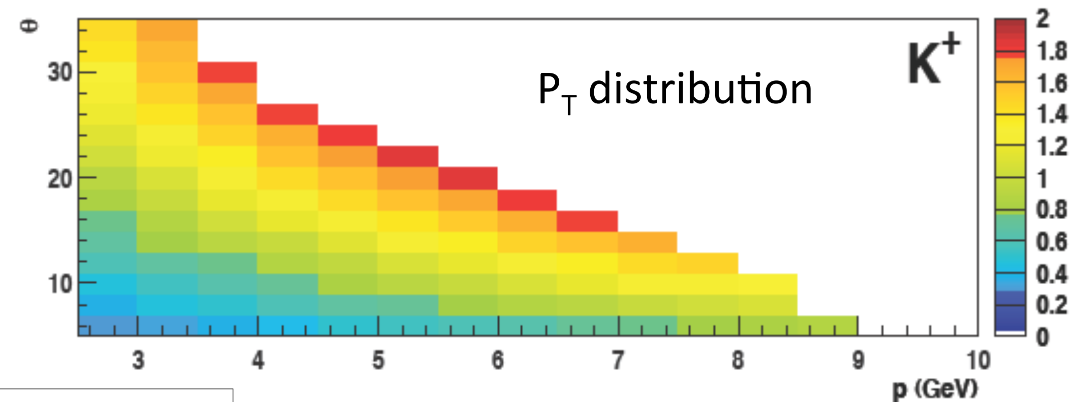
GOAL: 1st sector ready for physics run in 2016

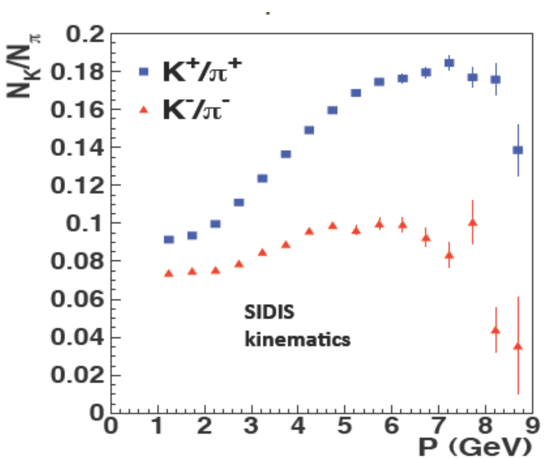
RICH Requirements

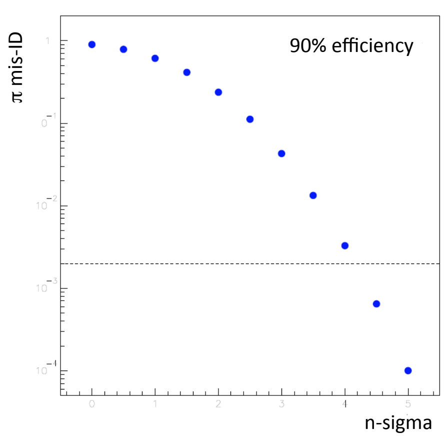
Full momentum coverage from 3 up to 8 GeV/c
Pion rejection above 3 GeV/c
Proton rejection above 5 GeV/c



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