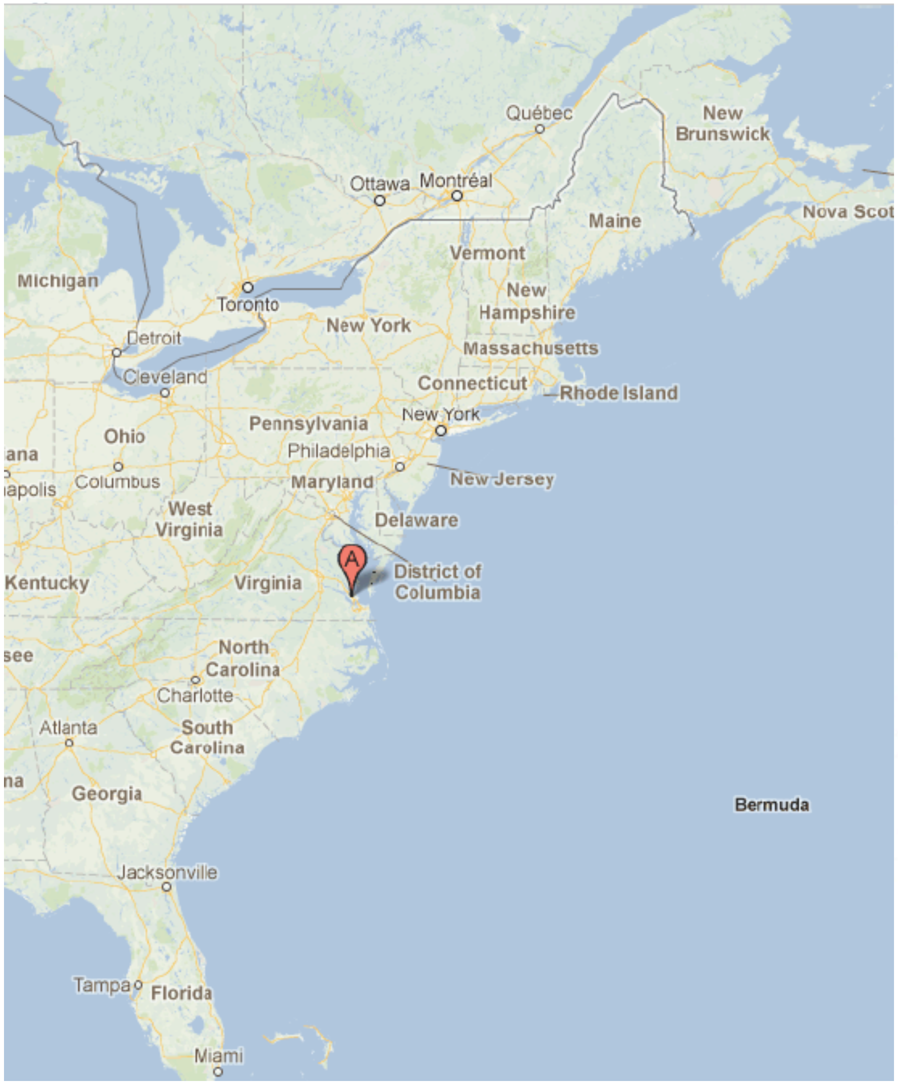
The CLAS12 RICH Project

Meeting with Hamamatsu, LNF – 31 May 2013

The JLAB12 Facility

Jlab Site @ Newport News, VA USA

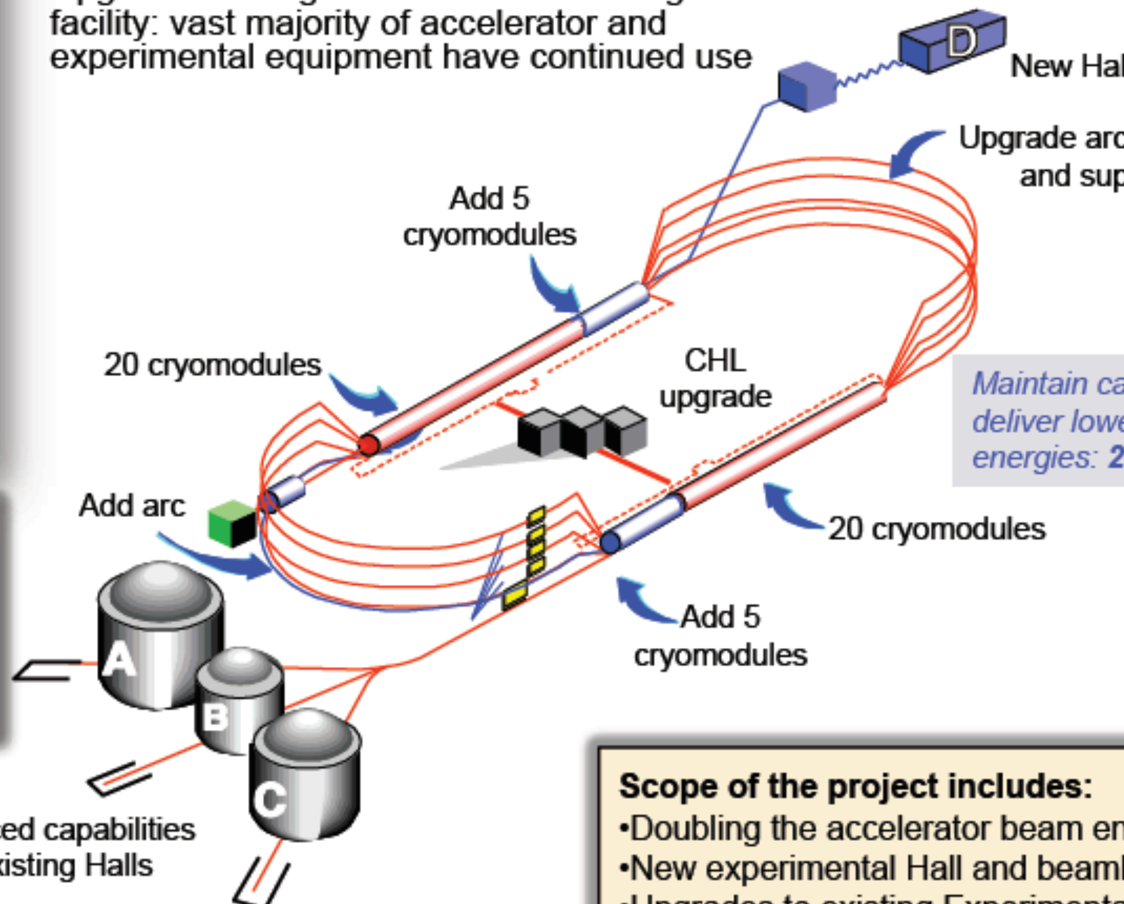


- Nuclear and nucleon structure study by eletron probe
- (Exotic) Meson/Barion spectroscopy
- from strong to perturbative QCD

12 GeV Upgrade Project

The completion of the 12 GeV Upgrade of CEBAF was ranked the highest priority in the 2007 NSAC Long Range Plan.

Upgrade is designed to build on existing facility: vast majority of accelerator and experimental equipment have continued use



*Maintain capability to deliver lower pass beam energies: **2.2, 4.4, 6.6….***

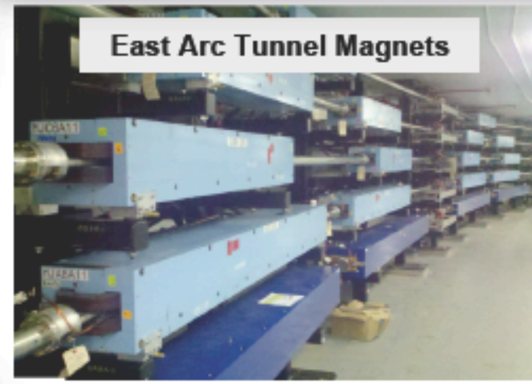
Scope of the project includes:
- Doubling the accelerator beam energy
- New experimental Hall and beamline
- Upgrades to existing Experimental Halls

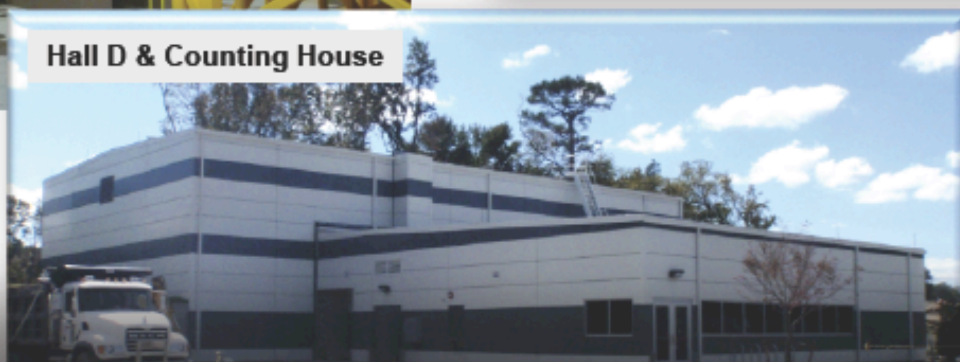
12 GeV Project Status


Hall D Interior


CHL-2 installation


3rd C100 cryomodule being transferred


East Arc Tunnel Magnets

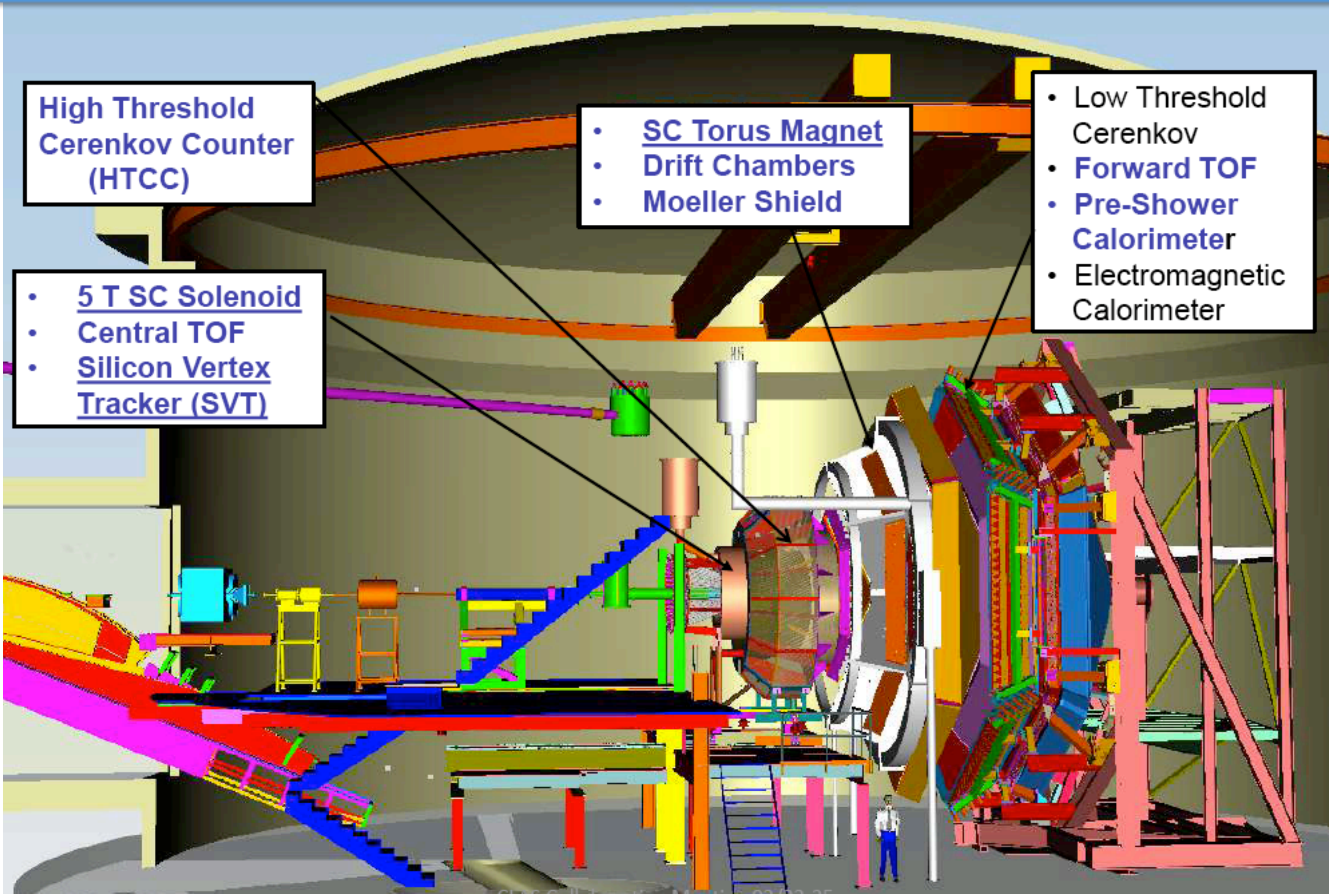

Hall D & Counting House


12 GeV Cryomodules/Waveguides

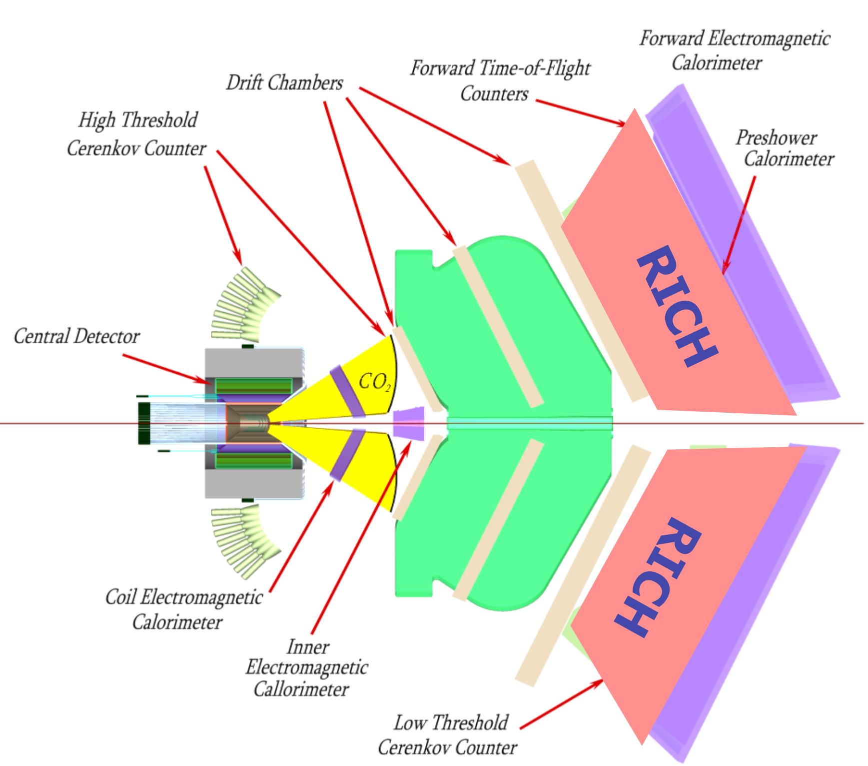
- Project 75% Complete, 88% Obligated
  - Civil (92%) ; Accelerator (88%) ; Physics Equip (~60%)
- We expect to be running beam to Hall A in February 2014 and Hall D later in the year
- Large user involvement in 12-GeV detector construction
- 7+ years approved, Halls have prepared initial schedule

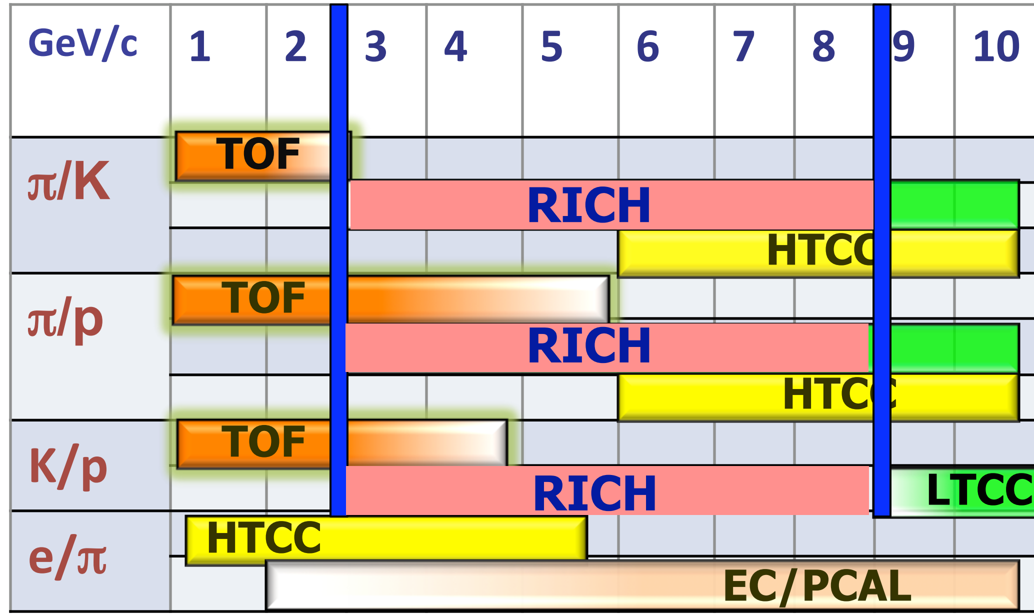
The CLAS12 RICH

CLAS12 in Hall-B



CLAS12 Particle Identification

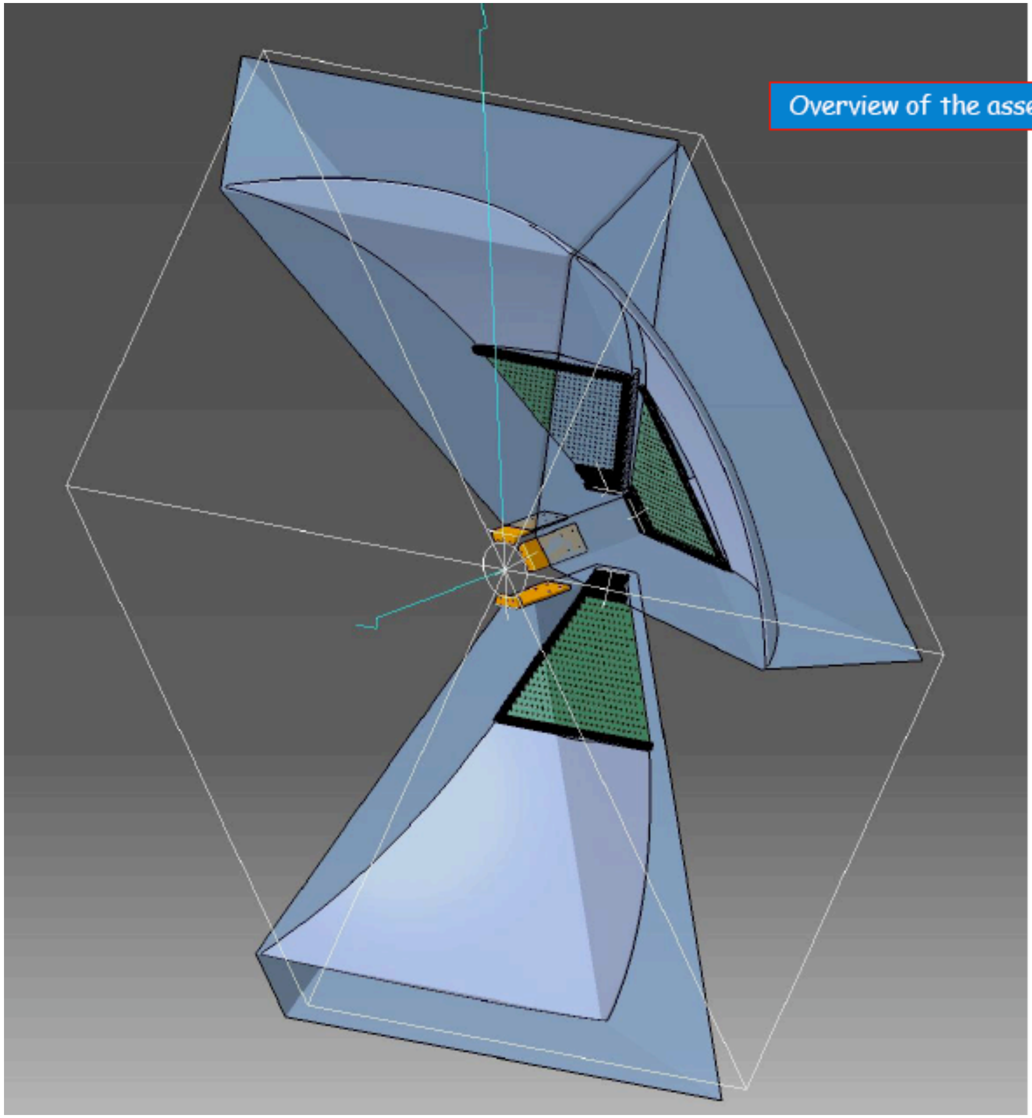




INSTITUTIONS
Jefferson Lab
INFN: Bari, Ferrara, LNF, Roma/ISS
Argonne National Lab
Duquesne University
Glasgow University
University of Connecticut
UTFSM (Chile)

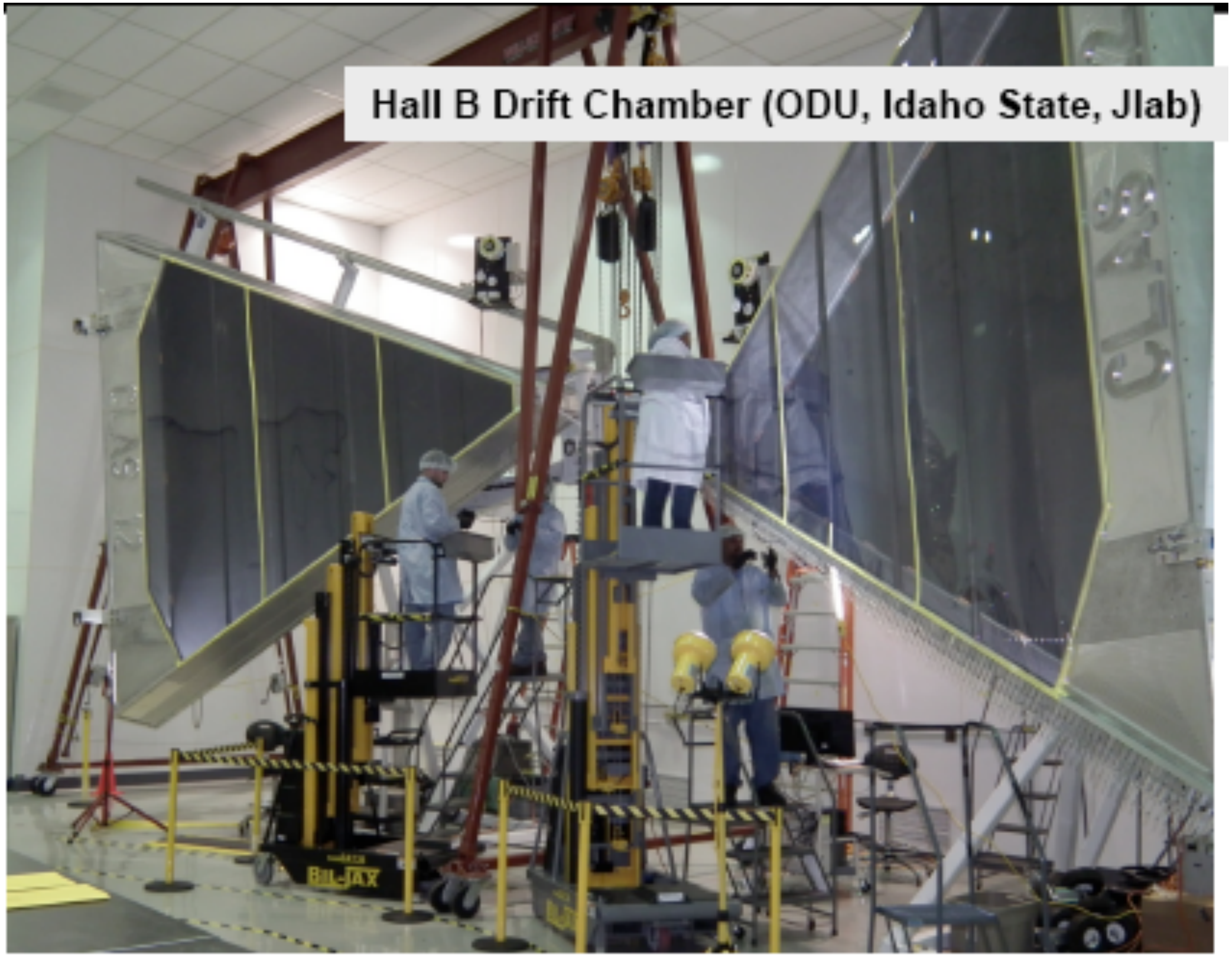
- **Aerogel** mandatory to separate hadrons in the 3-8 GeV/c momentum range
  - → collection of **visible Cherenkov light**
  - → use of **PMTs**
- **Challenging project,** need **to** minimize detector area covered with expensive photodetectors

Mechanical Design



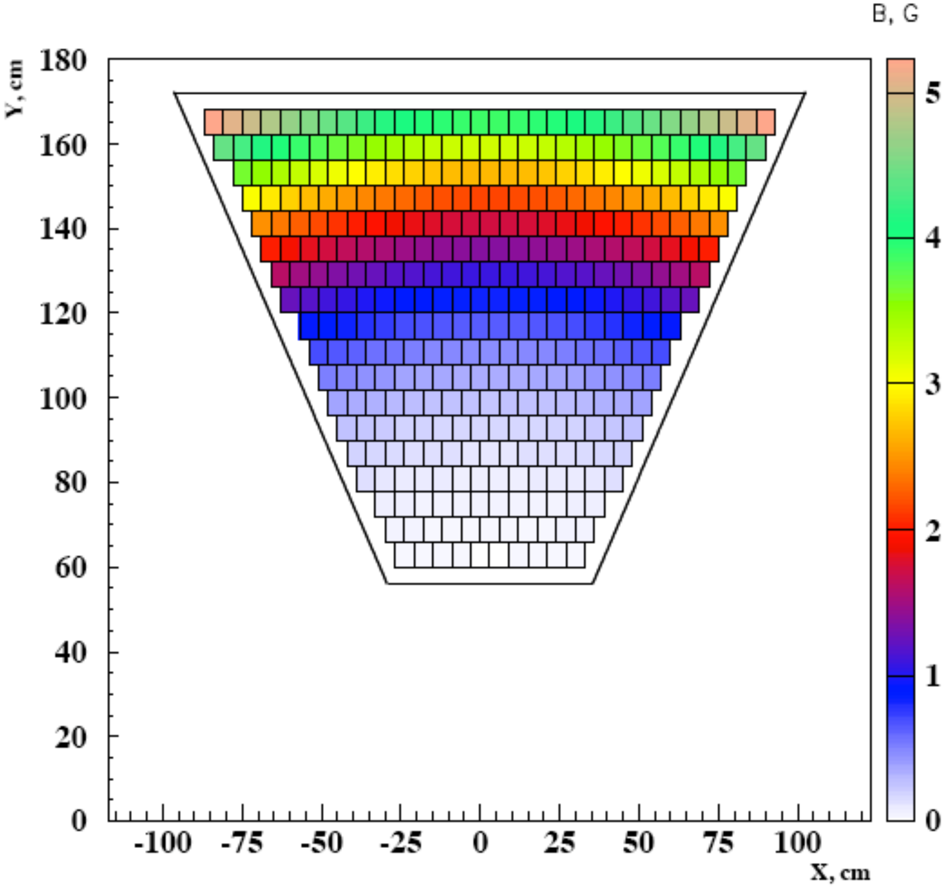
Overview of the assembled modules

Mechanical Design

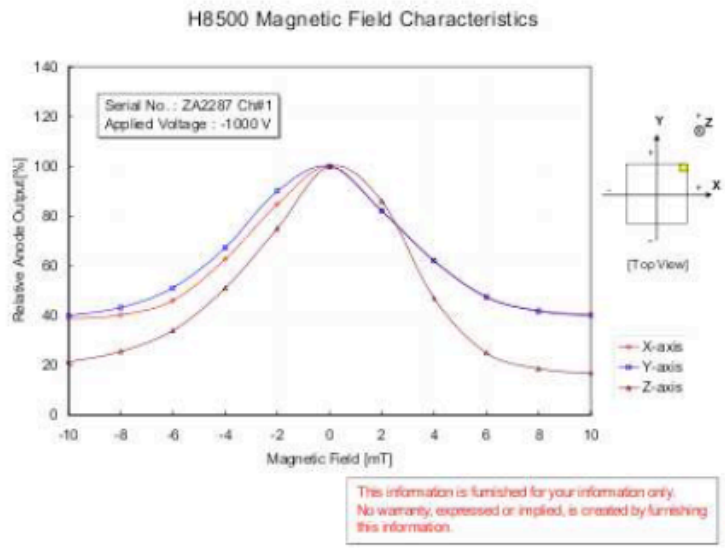


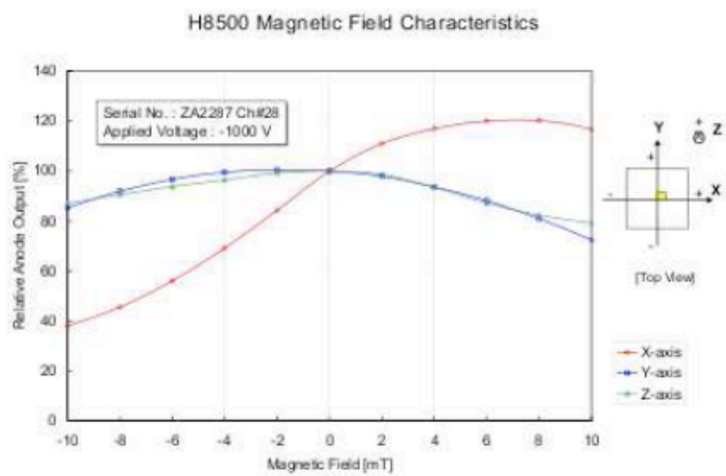
Hall B Drift Chamber (ODU, Idaho State, Jlab)

Magnetic Field



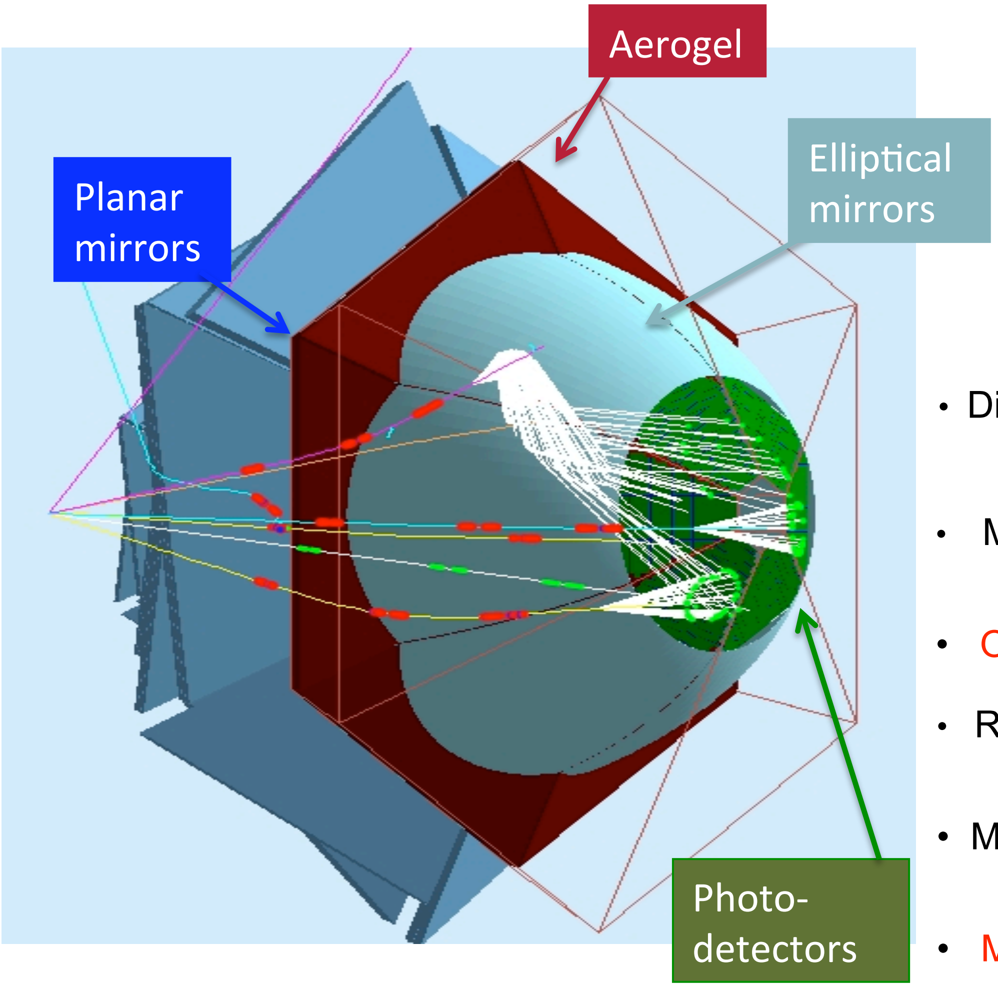
HAMAMATSU

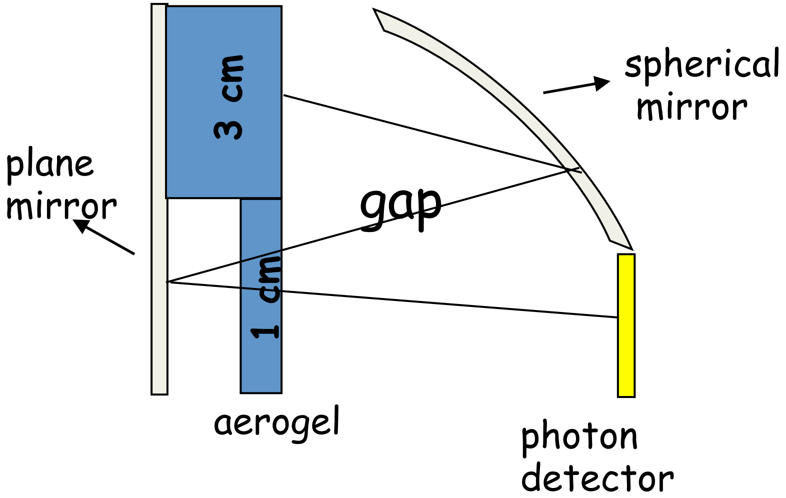




The Mirror System

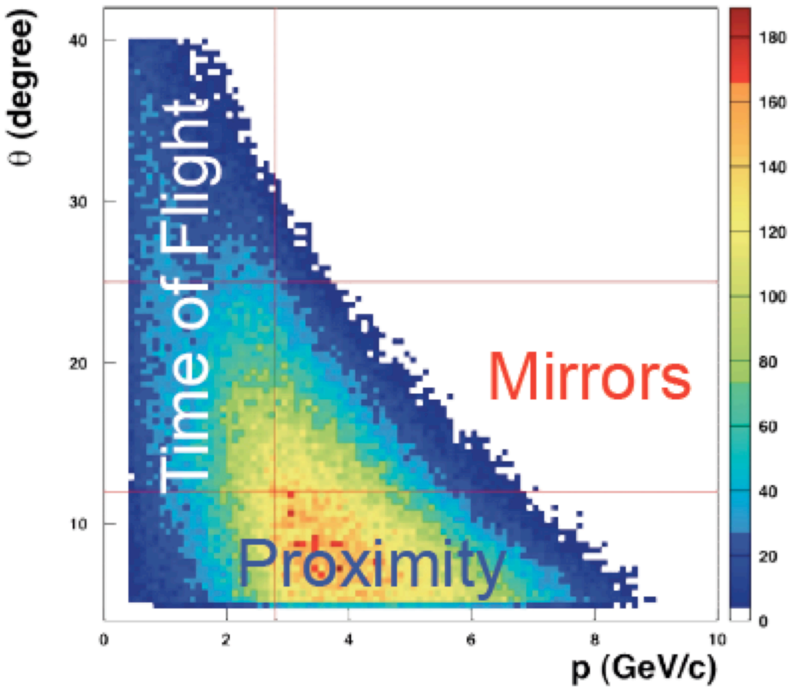
Proximity Focusing RICH + Mirrors

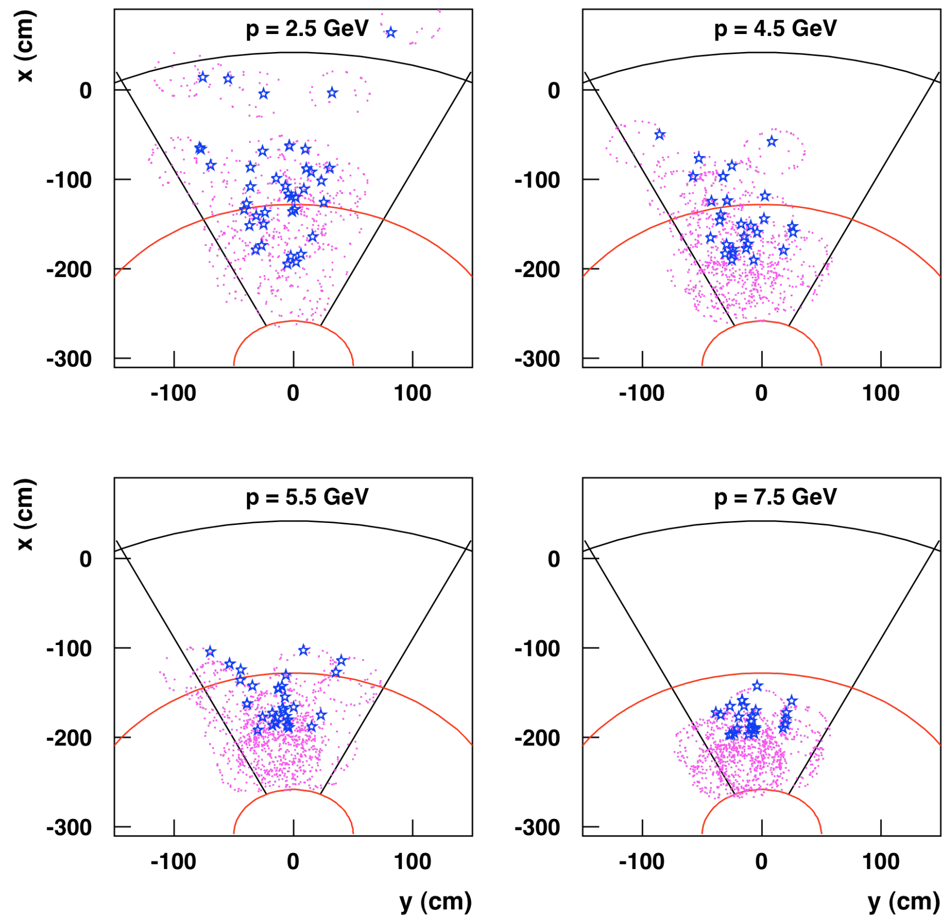




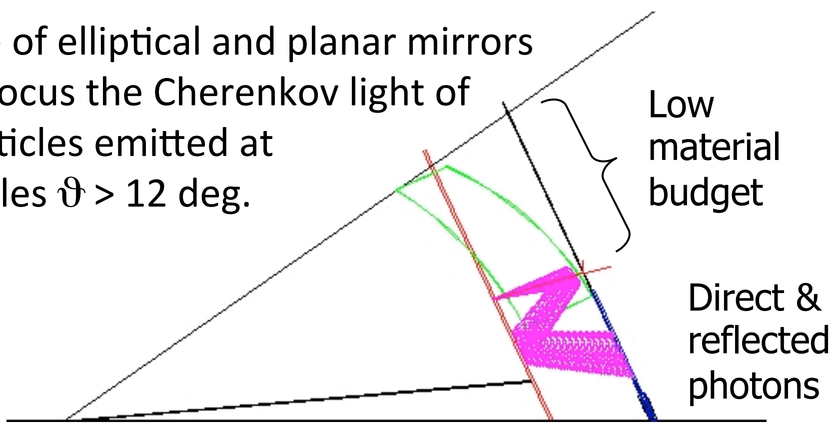
- Direct rings for high momentum particle → best performance !
- Minimize photon detector area → cost !
- Open detector close to beam line → background !
- Reflected rings for low momentum particle → less demanding
- Minimum interference with TOF
- Multiple passages within aerogel → photon losses
- Focalising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

The Mirror System





Use of elliptical and planar mirrors to focus the Cherenkov light of particles emitted at angles $\vartheta > 12$ deg.



Goals:

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

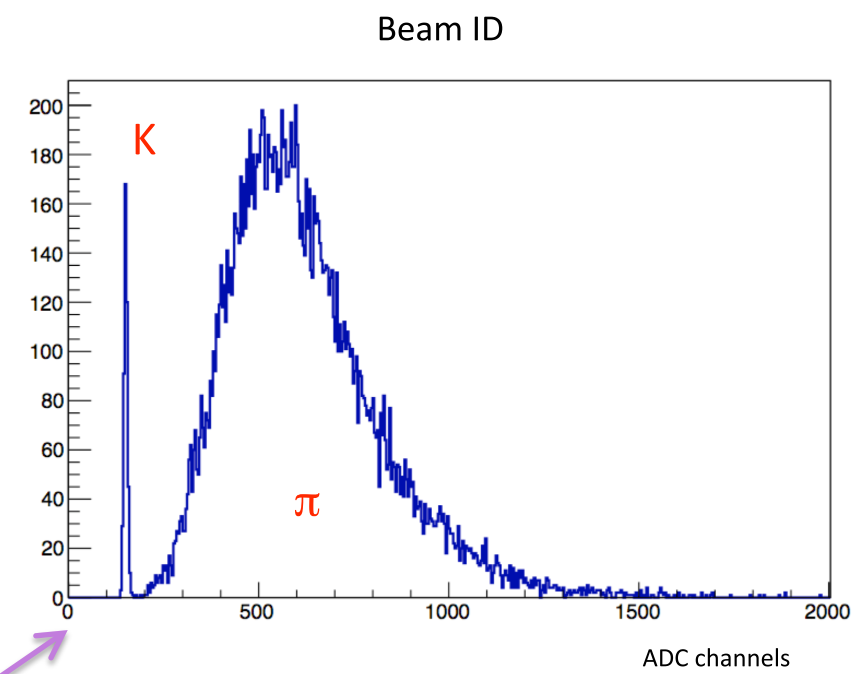
RICH News

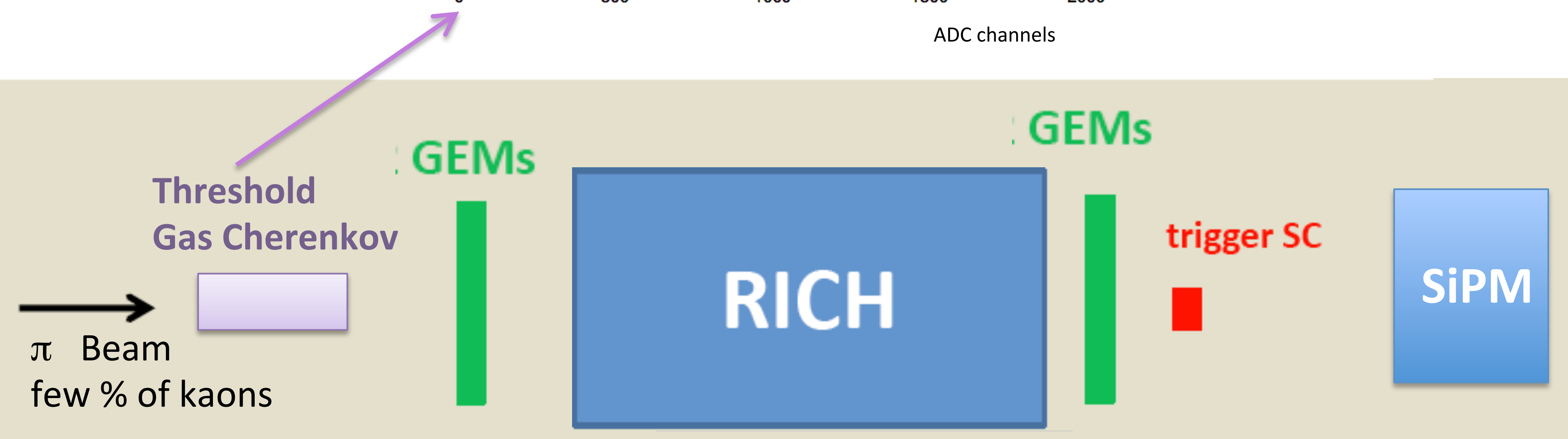
Past 6 months:

- ✔ July-12: test-beam with electrons (Frascati)
- ✔ July-12: test-beam with hadrons (CERN)
- ✔ Dec-12: test-beam with hadrons (CERN)
- ✔ Feb-13: Feb: start engineering phase
- ✔ Feb-Jun-13: intensive test-beam data analysis

The CLAS12 RICH Prototype

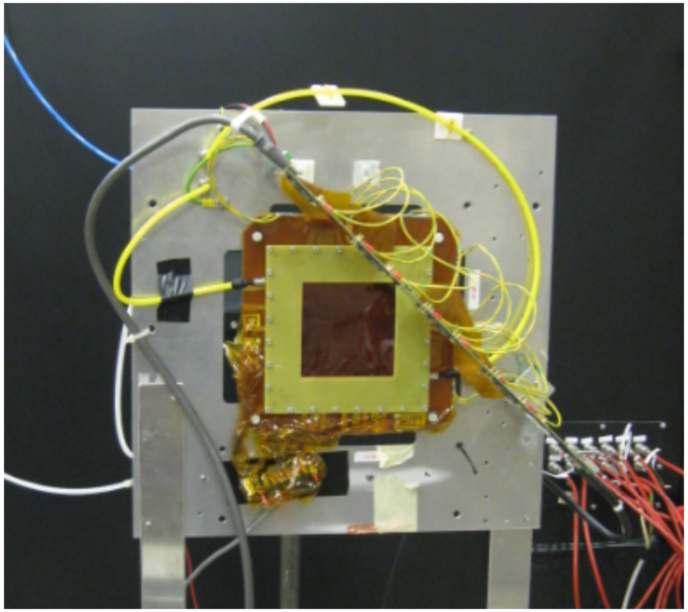
RICH Test Beam: Beam ID

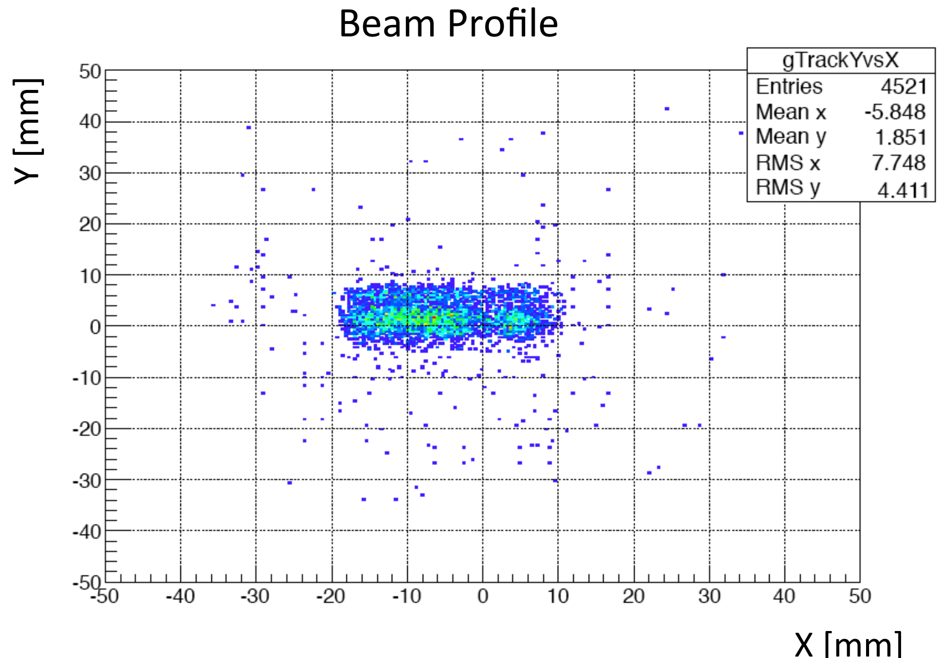


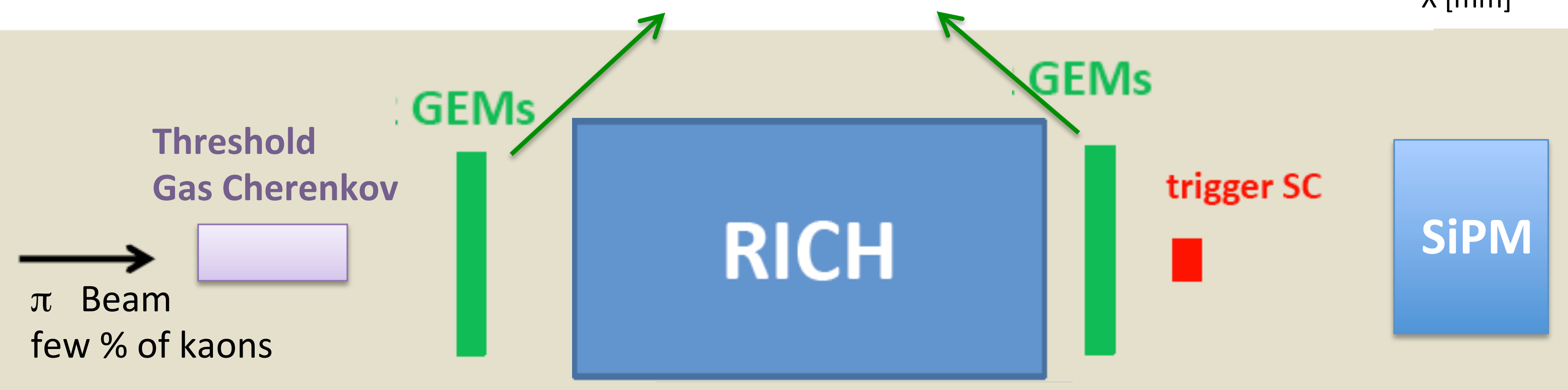


RICH Test Beam: GEM Tracking

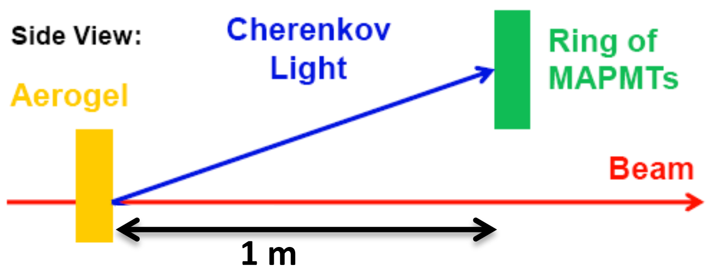
Two 10x10 cm^2 chambers with 256 strips in X and Y planes



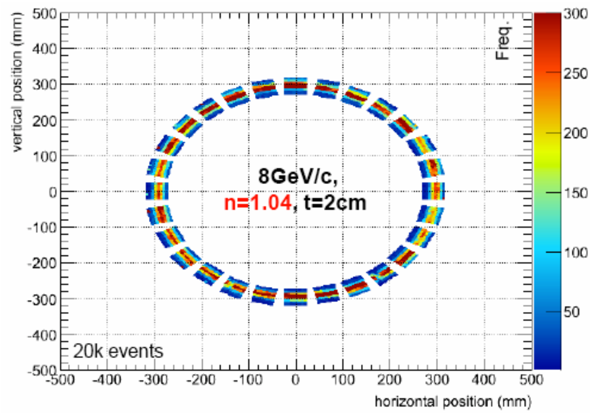


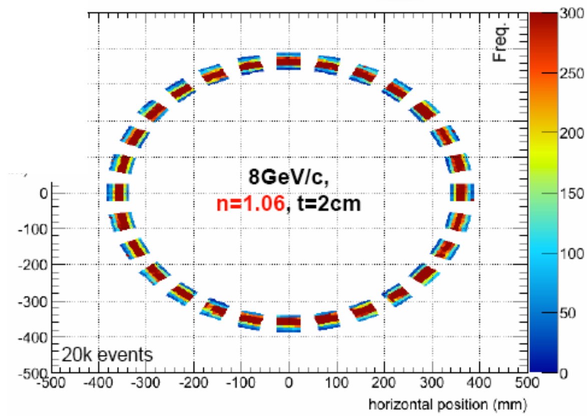


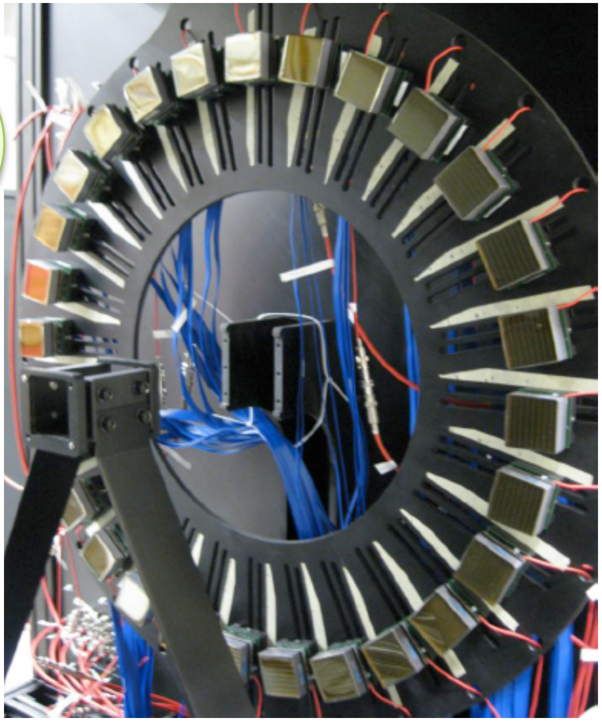
RICH Test Beam: Direct Light



Goal: measure the rejection power up to 8 GeV/c within the CLAS12 geometry







RING COVERAGE:

75% 62% 50%

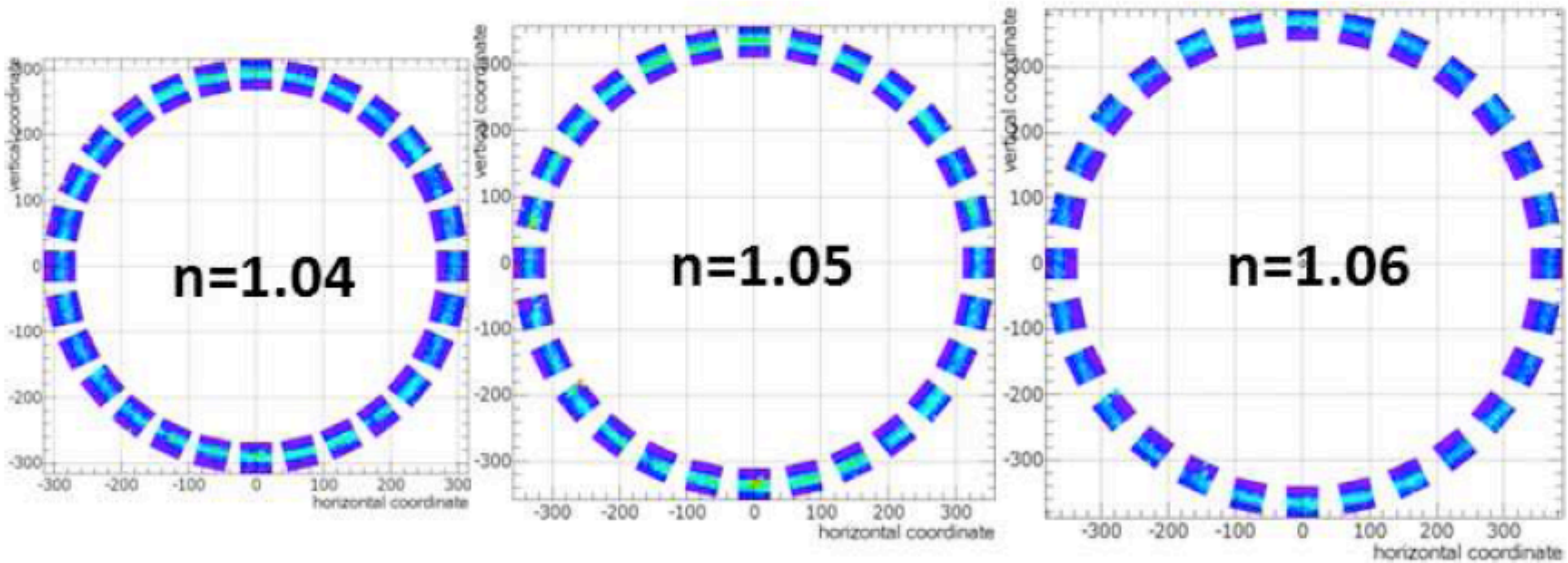


Figure 27: Cherenkov photon hit pattern measured with aerogel of different refractive index.

Separation vs Energy

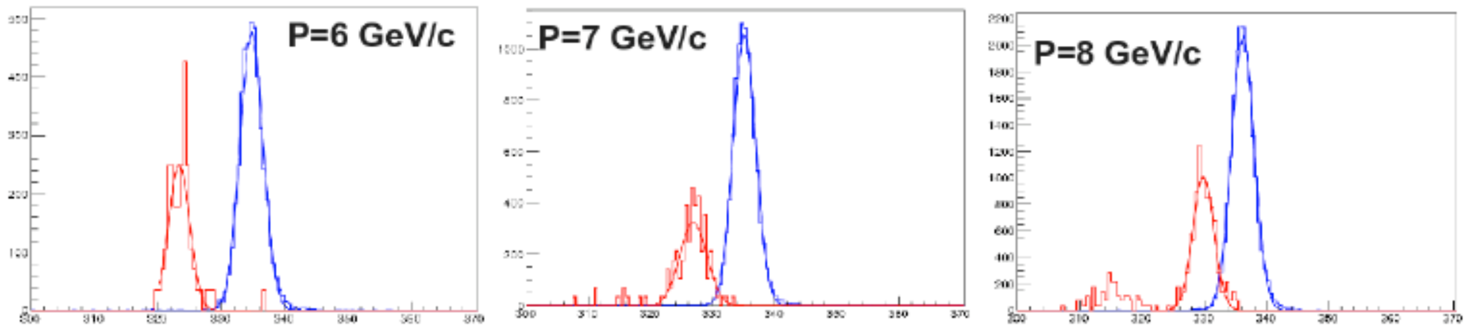


Figure 33: Pion ring radius distributions (blue histograms) compared with those from events with gas Cherenkov signal below threshold (red histograms), for $P = 6, 7, 8$ GeV/c beam (from left to right).

$$n_\sigma = \frac{\Delta R}{(\sigma_\pi + \sigma_K)/2}$$

P (GeV/c)	R(π) (mm)	σ(π) (mm)	R(K) (mm)	σ(K) (mm)	n(σ)
8	336.18±0.01	1.81±0.01	329.8±0.1	1.71±0.09	3.6
7	335.12±0.02	1.81±0.01	327.0±0.2	2.33±0.22	3.9
6	334.79±0.03	1.81±0.02	323.5±0.21	1.63±0.19	6.6

Background Hits

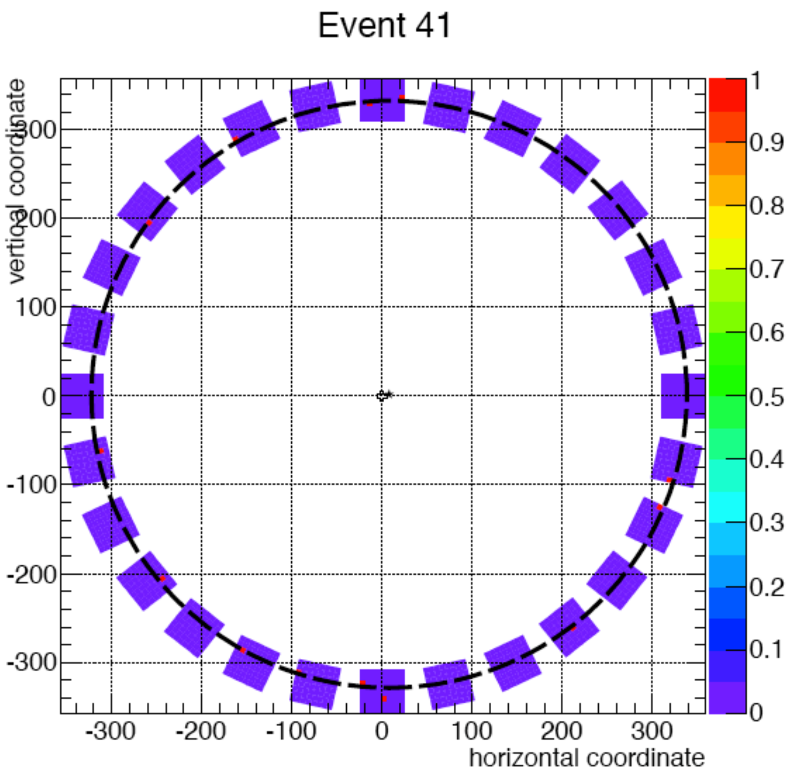


Figure 28: Hit distribution of one event measured with $n = 1.05$ and $t = 2$ cm aerogel. The circle show the Cherenkov ring fitted to the hits.

Background rate at the level of
3 x 10^{-4} per pixel

About 70 % associated to the aerogel
from "empty target" runs

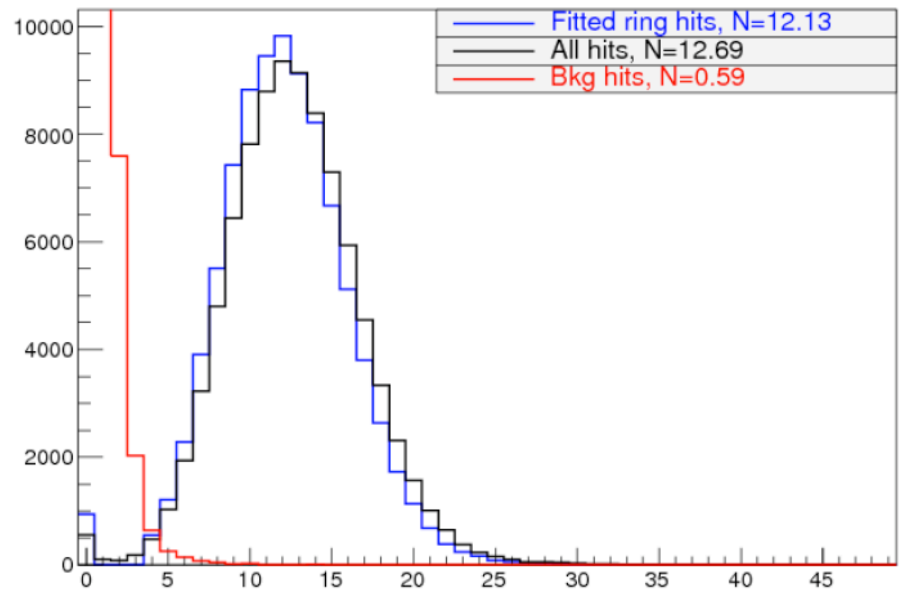


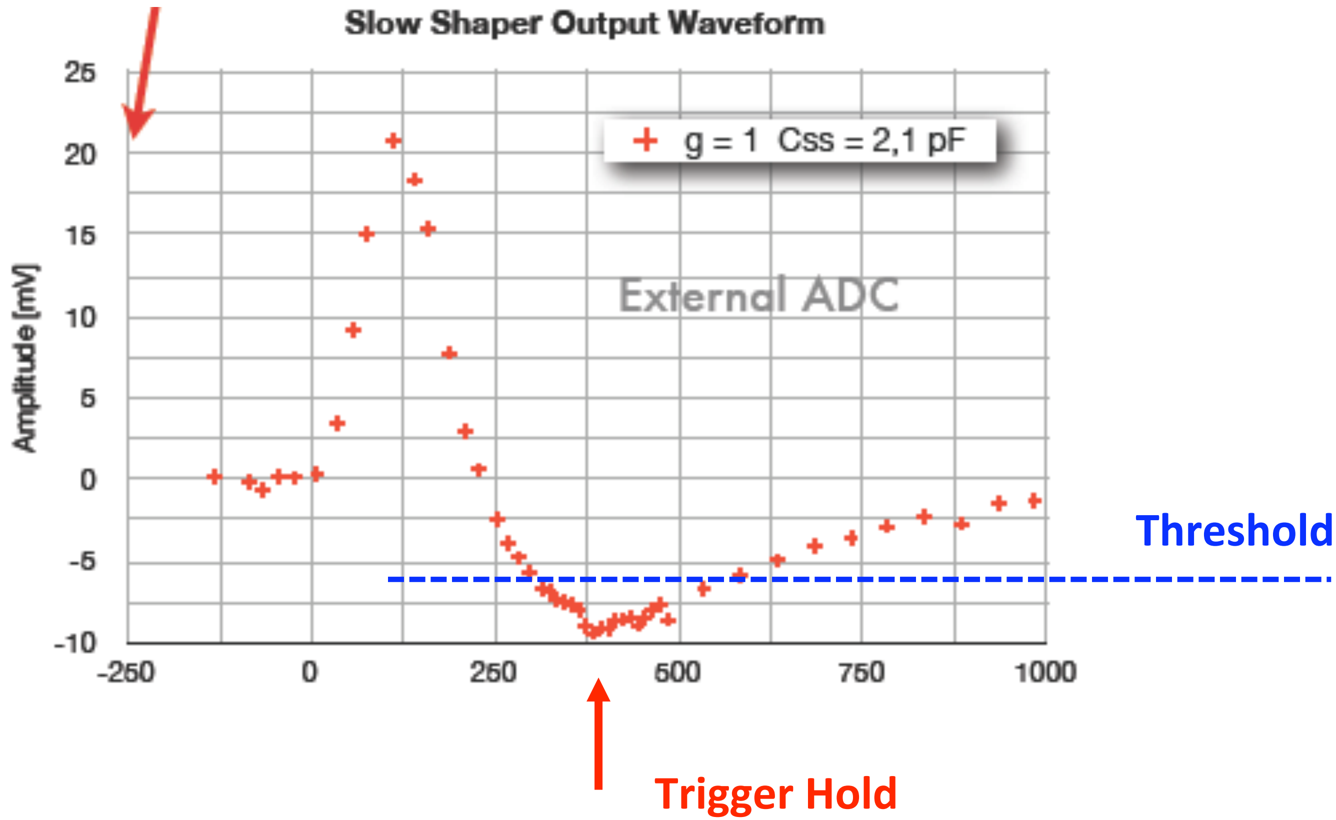
Figure 29: Number of MAPMT hit per event: all hit above threshold (black histogram), background hits (red histogram) and Cherenkov hit (blue histogram). Mean values of the distributions are reported in the legend.

Readout Time-Window

A “empty target” background rate at the level of 1 x 10^{-4} in a time window of few hundreds ns corresponds to a dark count rate of 0.4 KHz per pixel.

Is it compatible with the expected H8500 dark-count at 1750 V ?

Need to correlate data-sheet dark current with dark counts with MAROC3 readout



UV-window MA-PMTs

UV-window H8500 provides ~ 1 p.e. more than normal PMT
but at the price of an increased spread in resolution

Standard PMT is the preferred option

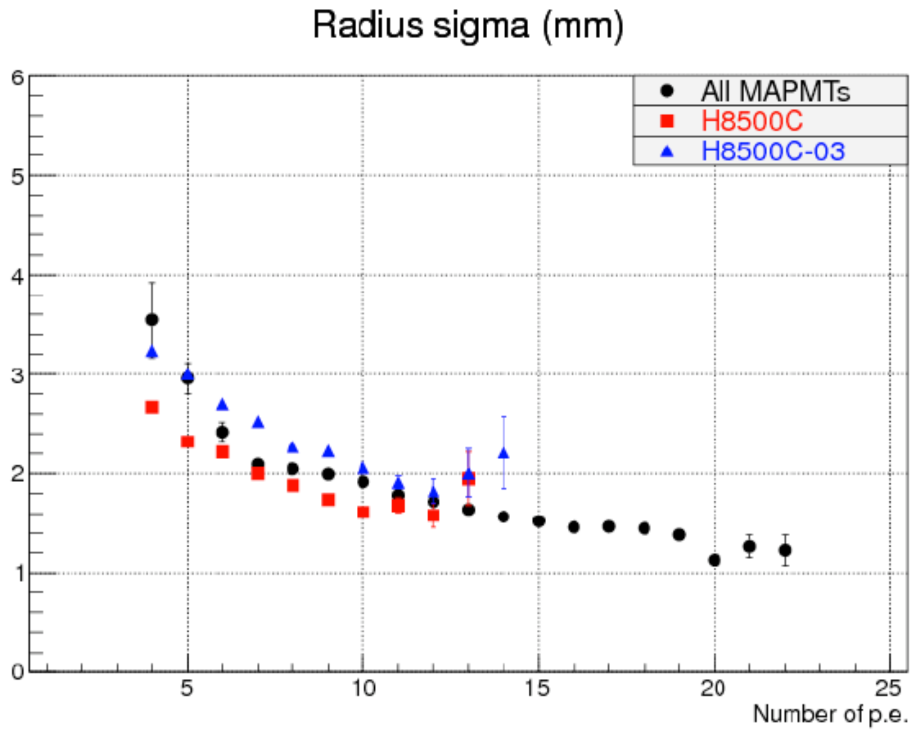
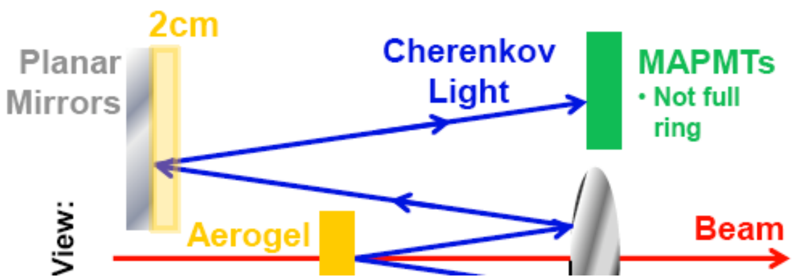
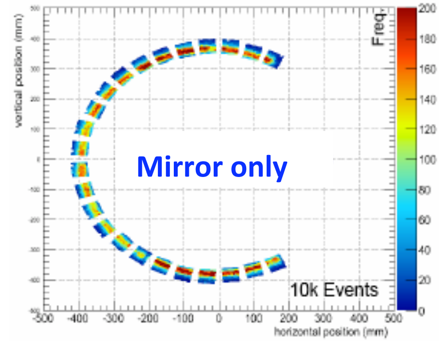
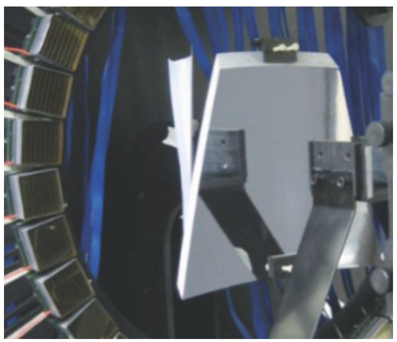


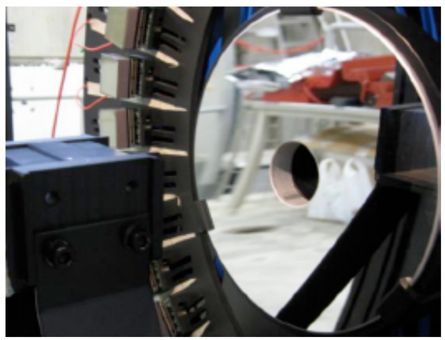
Figure 36: Gaussian width of Cherenkov ring radius as a function of N_{pe} measured with 14 UV-enhanced glass MAPMTs (blue triangles), with 14 normal glass MAPMTs (red squares) or with all the 28 MAPMTs (black circles).

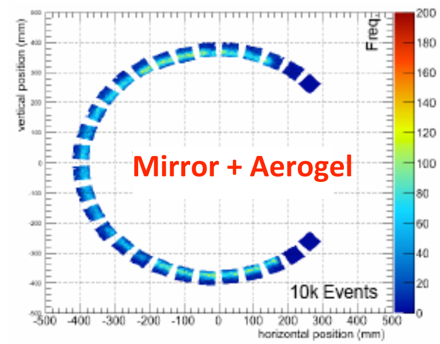
RICH Test Beam: Reflected Light

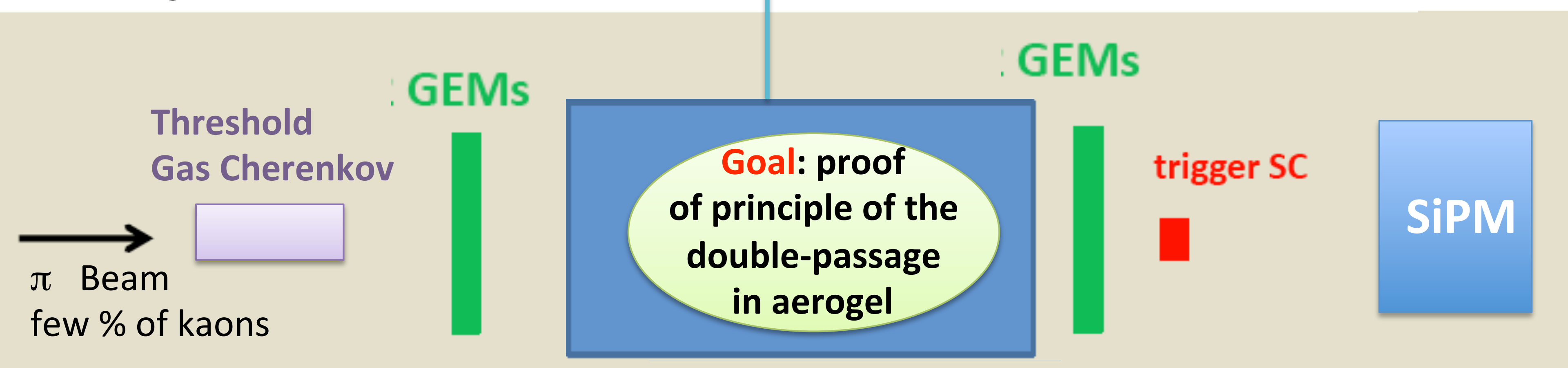





Jlab light mirror

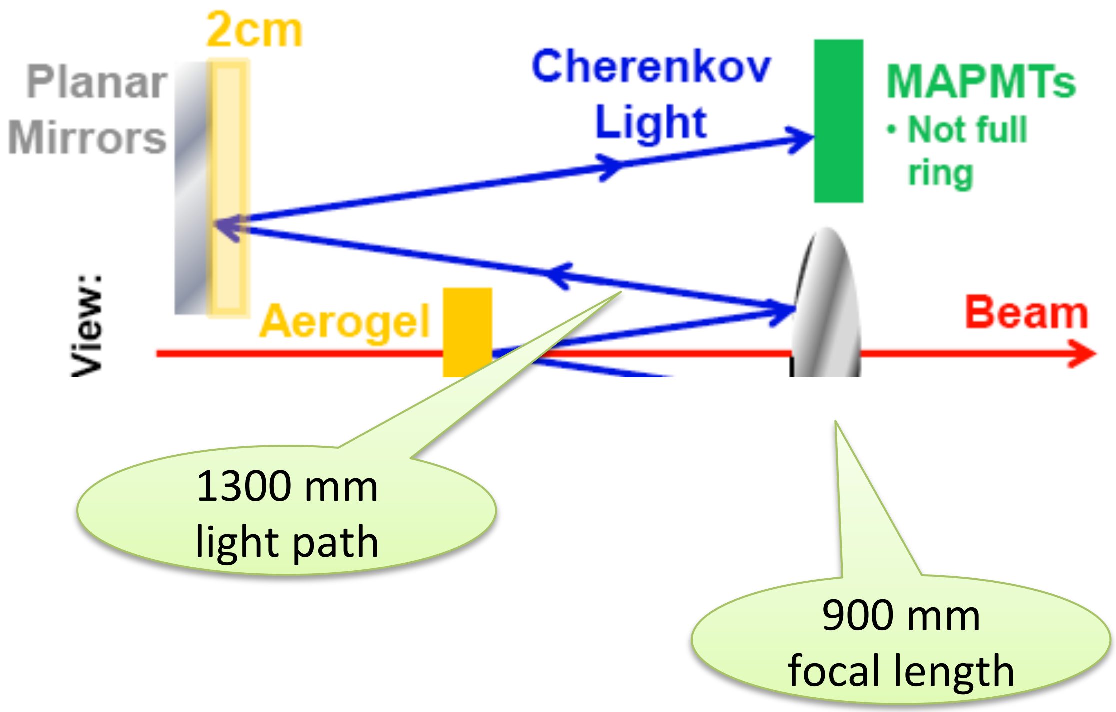

Marcon glass mirror





The Reflected Light Case

Aerogel n=1.05, Beam P = 6 GeV/c



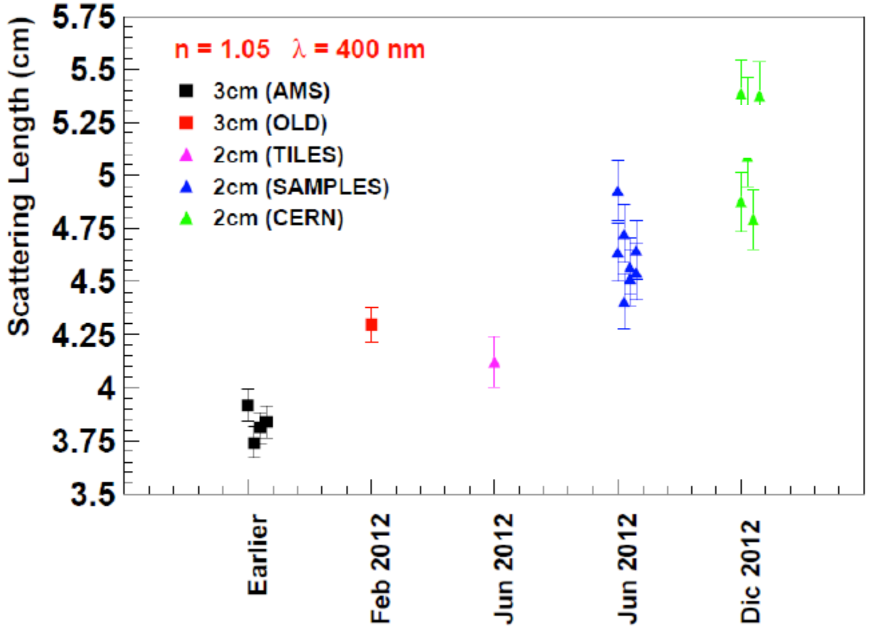
Main goal: Measure Photon Yield

Study contributions to the resolution

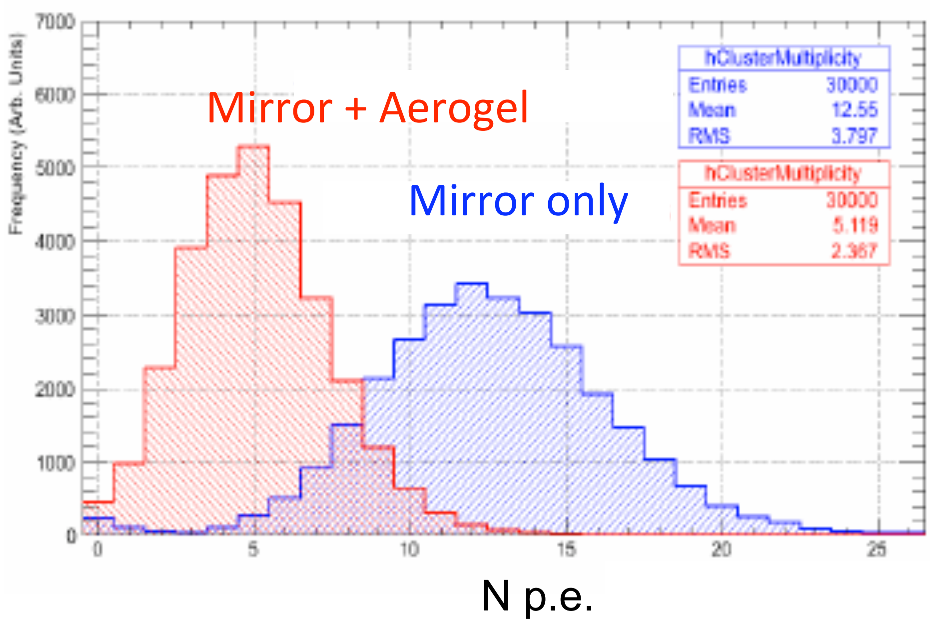
Geometry is not suitable for good n-sigma separation

Reflected Light Photon Yield

Aerogel improvement in Time

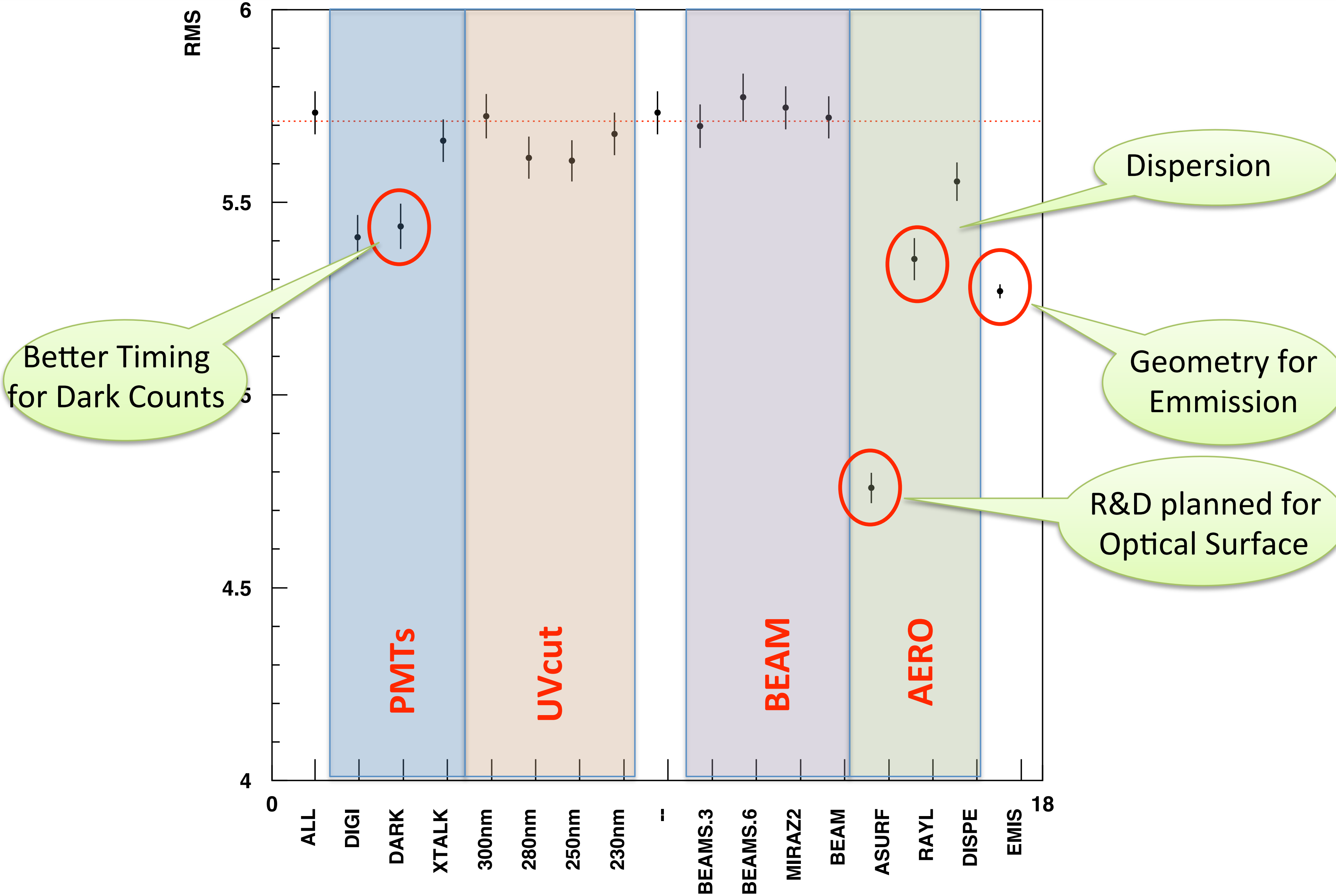


60% p.e. yield loss matches the requirements

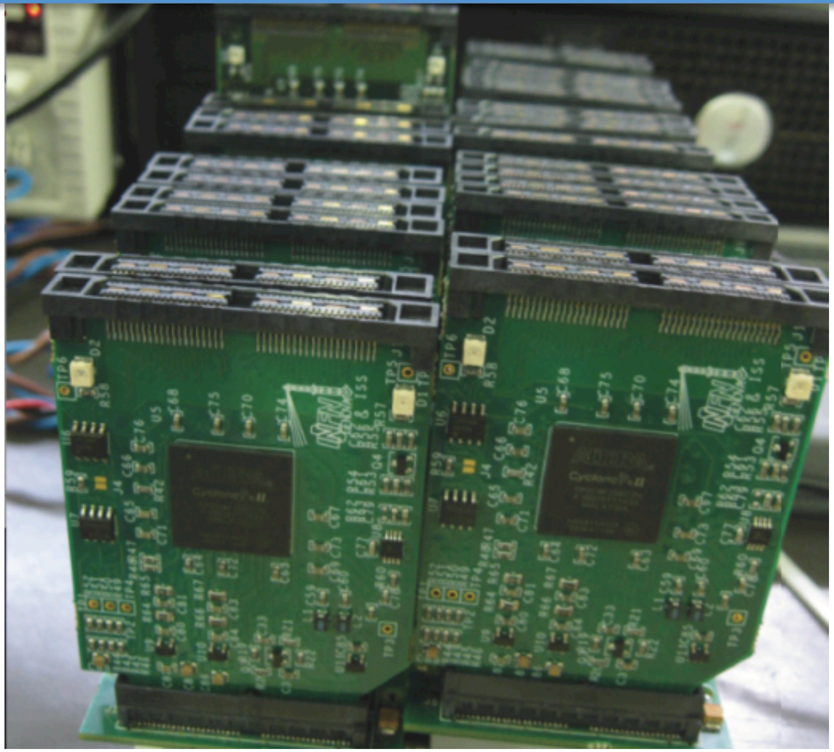


Russian producer estimates 6 cm of transmission length is feasible in massive production

Contributions to the Resolution



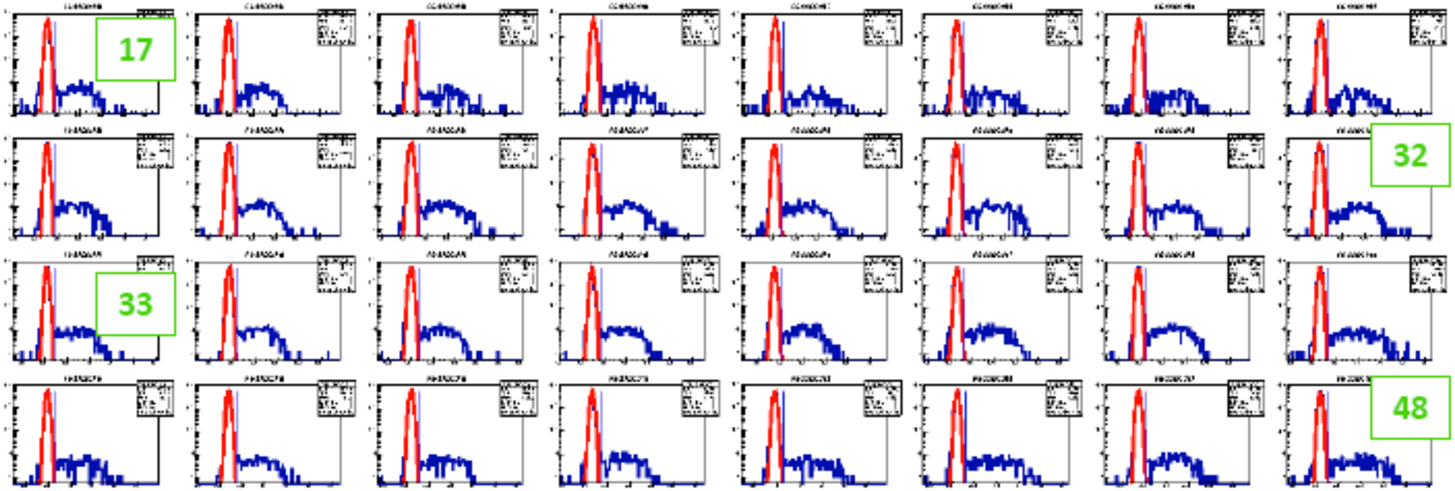
MAROC3-chip Readout Principles



Compact Design
(4096 channels in a shoe-box)

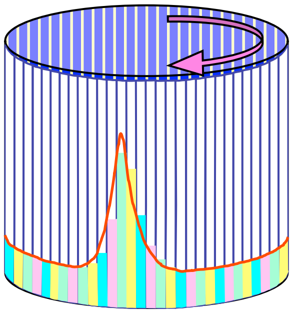
Analog (slow) or
Digital (fast) readout

After common noise subtraction

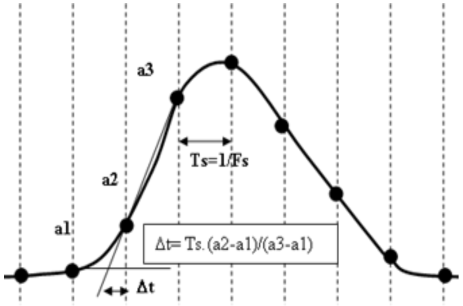


DREAM-chip Readout Principles

- Signals are continuously pre-amplified, shaped, sampled at 20-30 MHz and kept in a circular analog memory
  - Deep enough to sustain 16 μs trigger latency



- At each trigger 4 - 6 corresponding samples are readout and digitized
  - Readout does not disturb sampling
- Retained samples are digitally processed
  - Pedestal equalization – online
  - Common noise subtraction – online
  - Zero suppression – online
  - Measure charge and time – off-line



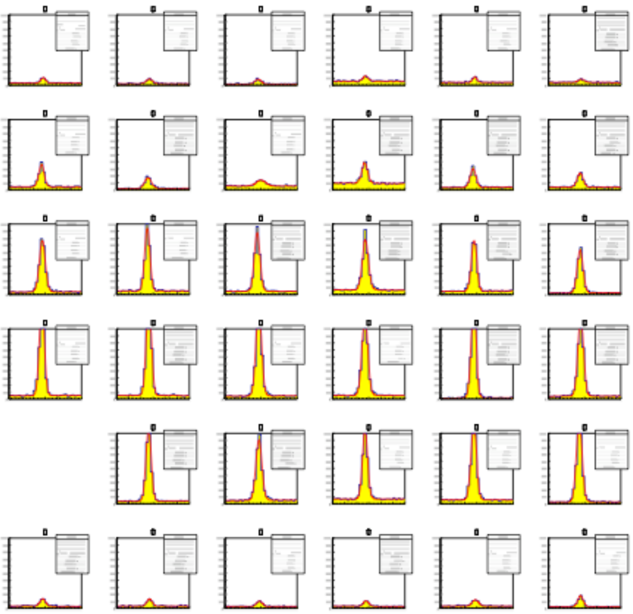
RICH outlook

Next 6 months:

- ✔ Feb-Jun: finalize test-beam data analysis
- ✔ Mar-Jun: update the CLAS12 RICH project and CDR
- ✔ August: pre-review at JLab
- ✔ July: test-beam dedicated to electronics
- ✔ August: review with DOE
- ✔ September: start procurement

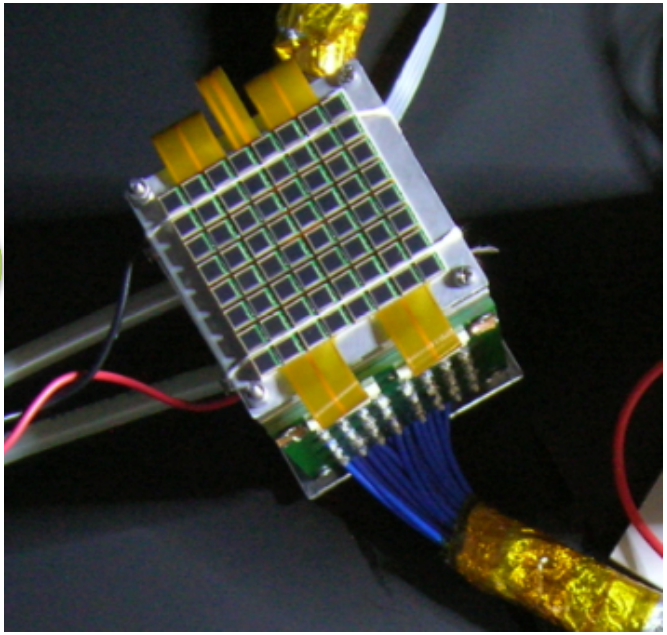
RICH Test Beam: SiPM

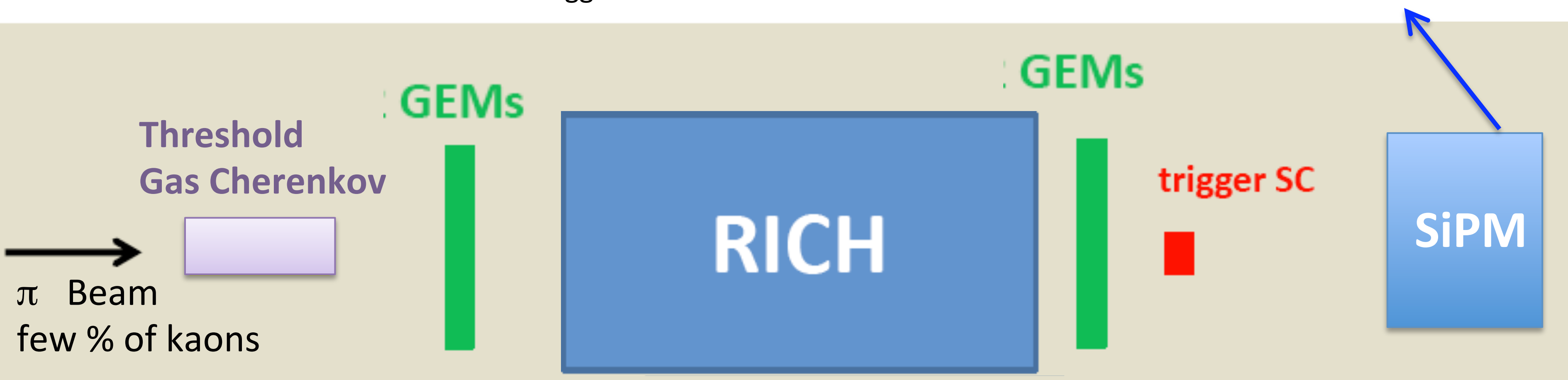
Cherenkov Ring Profile



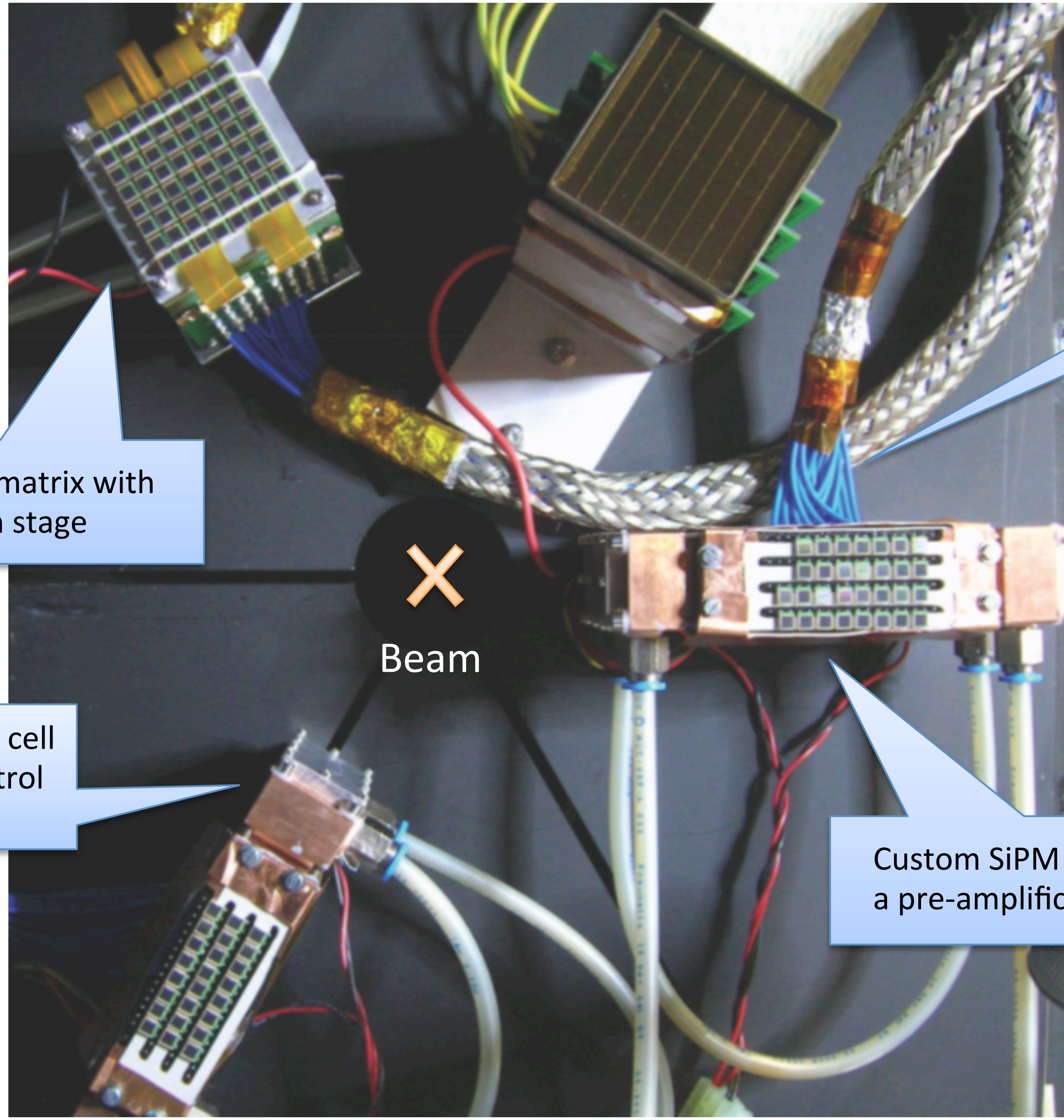
Δt with trigger

Goal: compare SiPM matrix vs H8500 performances



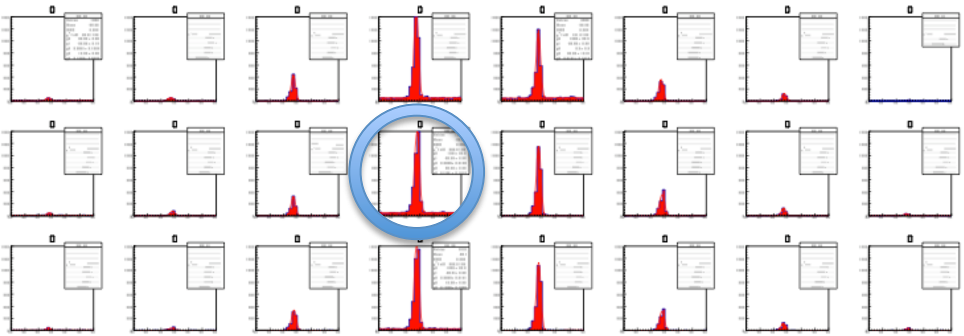


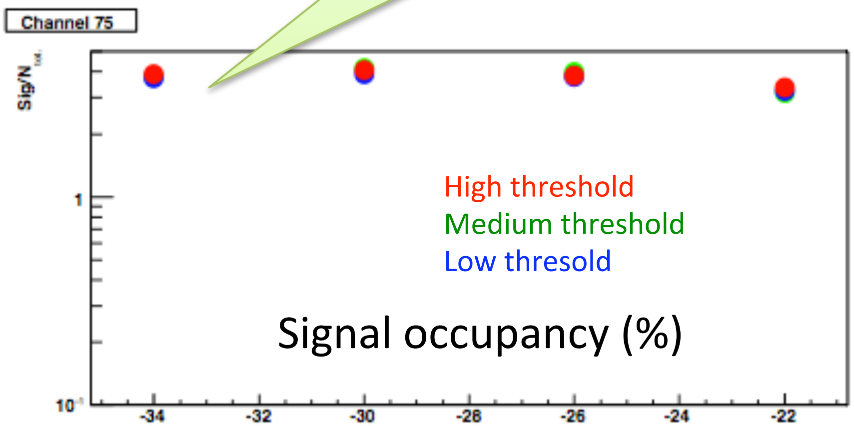
The SiPM Prototype



The Custom SiPM Matrix@-25°

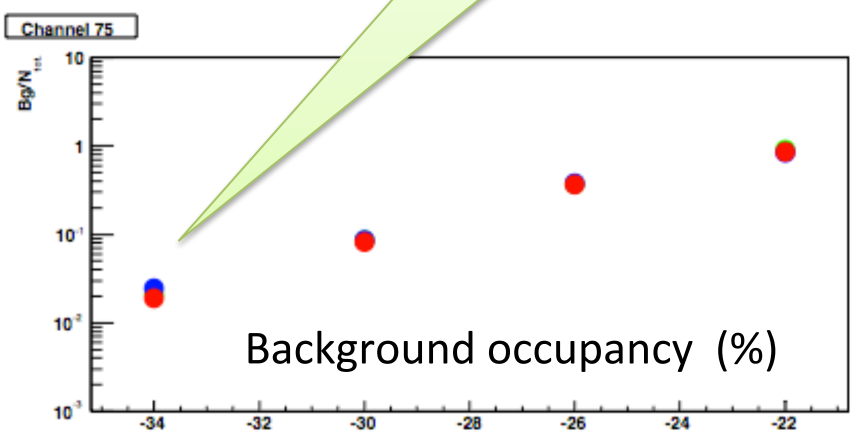
Largely insensitivity to Vbias and discriminator threshold



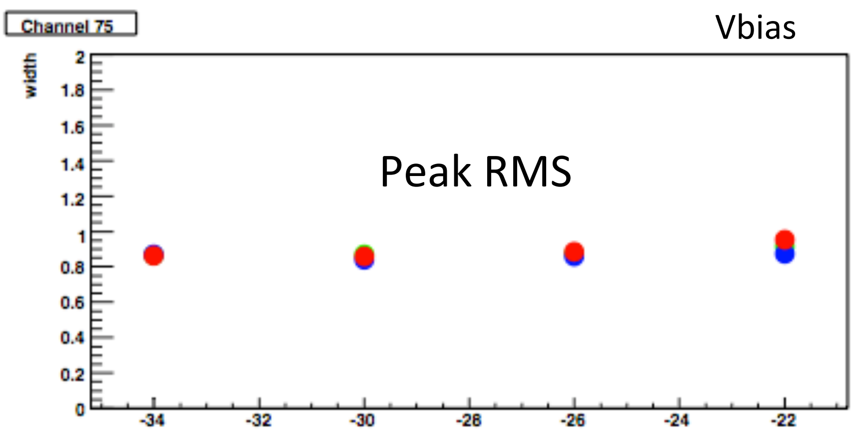


Vbias

In a +/- 3 ns window
Comparable with H8500



Vbias



Vbias

Average Number of Hits per Event

Device	T	Hits per event	N p.e.
Good Pixels	-25°	0.04	22.6
Good Pixels	+25°	0.04	22.6
Matrix 1	-25°	0.770	24.2
Matrix 2	-25°	0.320	26.8
Matrix 3	-25°	0.223	22.4

Consistent with a factor 2 in QE with respect H8500

Conclusion:
Cooled SiPM are a valid alternative to H8500