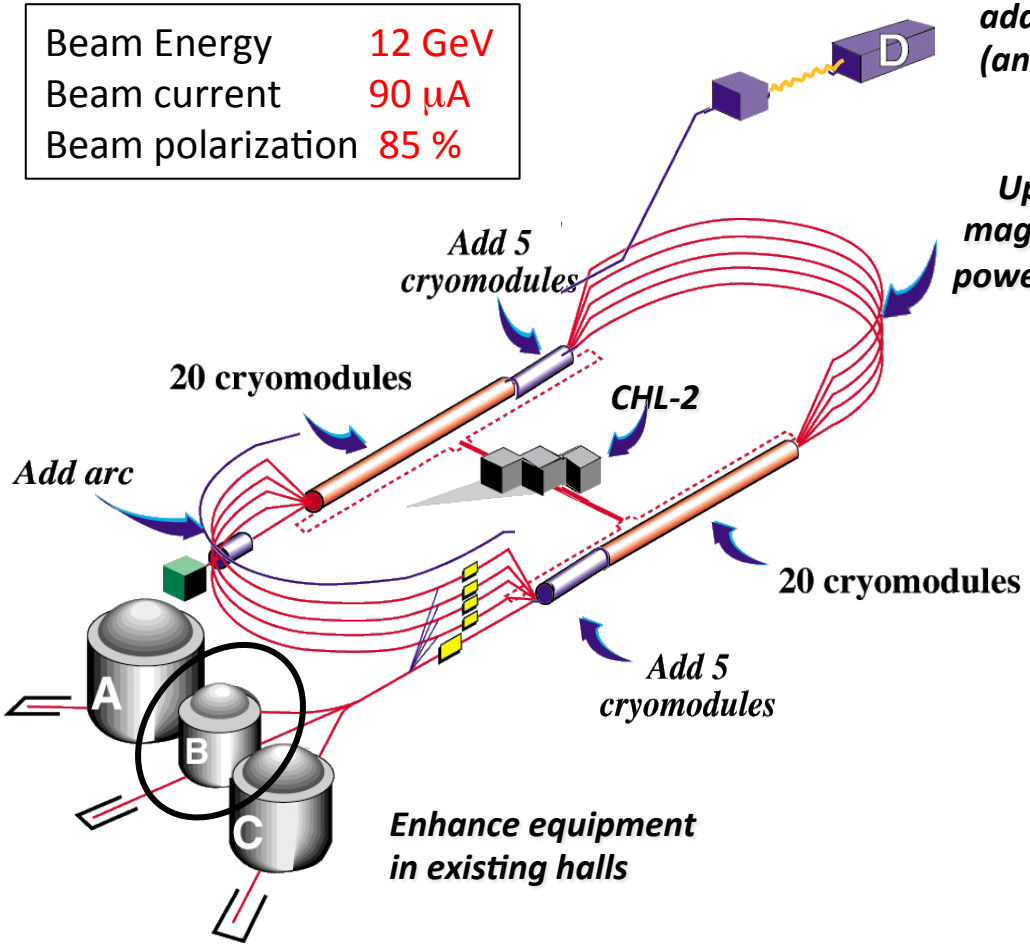
TEST OF INNOVATIVE PHOTON DETECTORS AND INTEGRATED ELECTRONICS FOR THE LARGE-AREA CLAS12 RICH

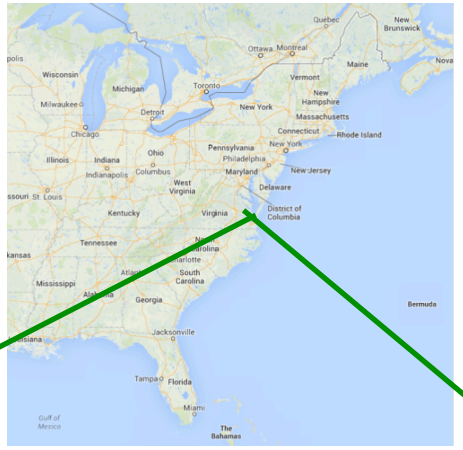
Contalbrigo Marco
INFN Ferrara
On behalf of the CLAS12 RICH Group

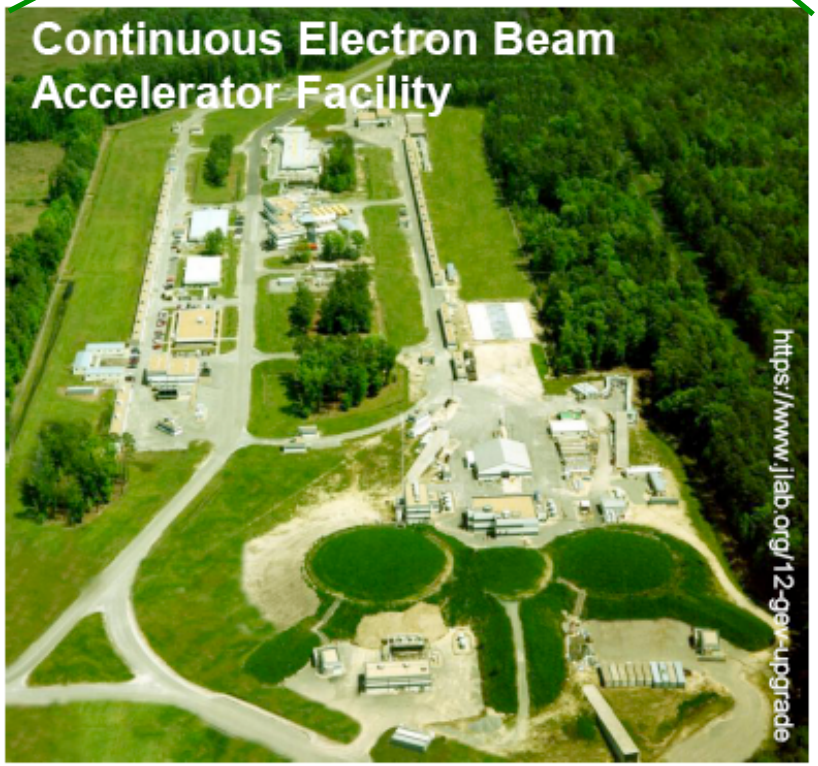
7th NDIP Conference, 2nd July 2014, Tours - France

CEBAF Upgrade at Jefferson Lab

Beam Energy	12 GeV
Beam current	90 μA
Beam polarization	85 %







- Nucleon structure & Nuclear effects
- Hybrid mesons (gluonic excitations)
- Low-energy tests of SM
- Heavy photon search

The CLAS12 Spectrometer

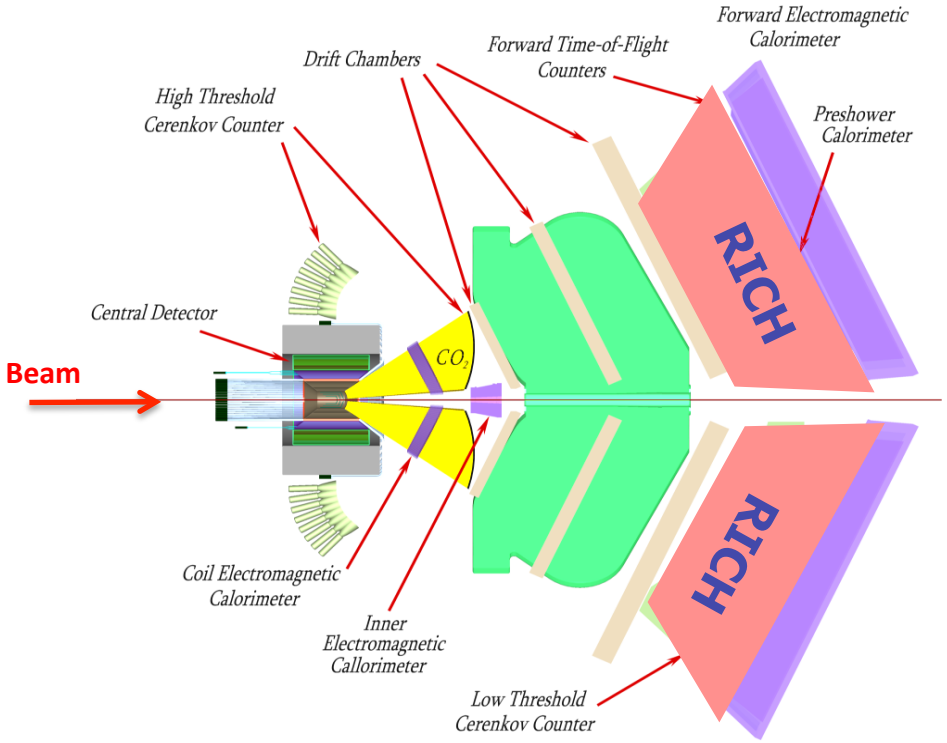
Ongoing upgrade of the CLAS detector.
First beam expected in 2016.

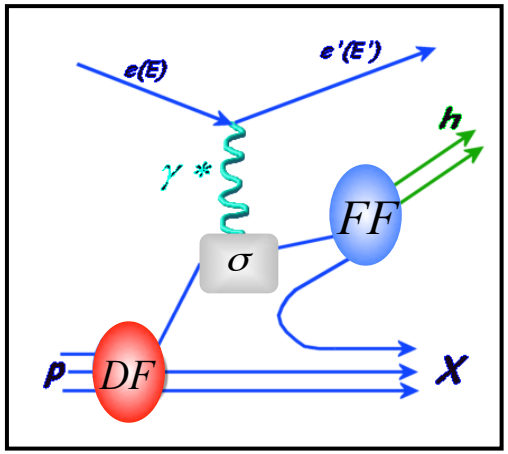
Highly polarized 12 GeV electron beam

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

H and D polarized targets

Broad kinematic range coverage
(current to target fragmentation)





3D structure of the nucleon by
polarized deep-inelastic scattering

Hadron ID wanted for flavor separation

Crucial for the study of parton dynamics related to angular momentum and spin-orbit effects with flavor sensitivity.

The CLAS12 Spectrometer

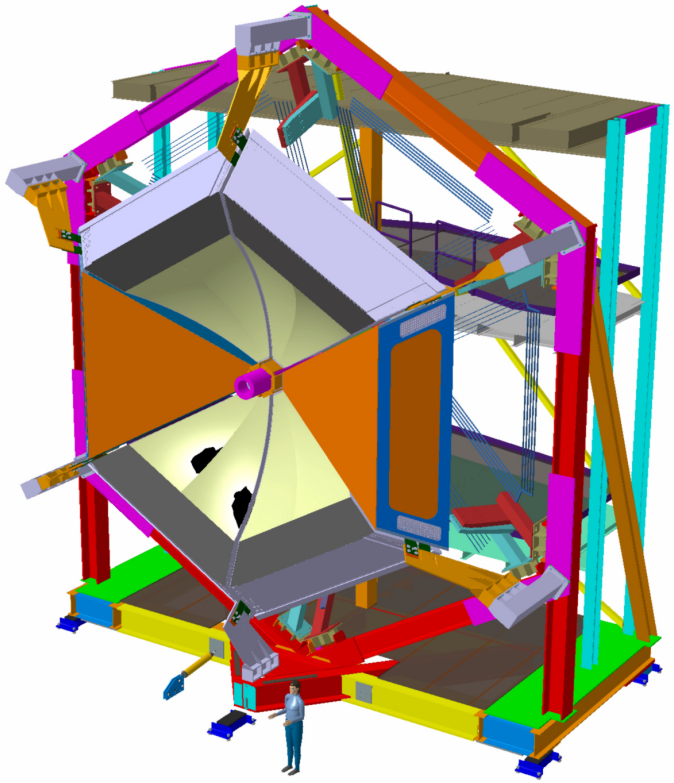
Ongoing upgrade of the CLAS detector.
First beam expected in 2016.

Highly polarized 12 GeV electron beam

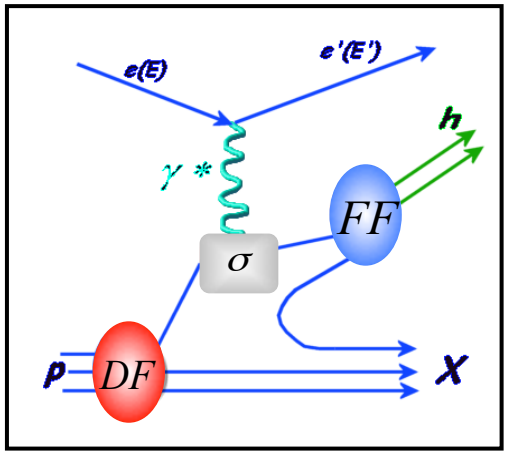
Luminosity up to 10^{35} cm^{-2} s^{-1}

H and D polarized targets

Broad kinematic range coverage
(current to target fragmentation)



2 sectors to accomplish physics program,
1st sector by the end of 2016

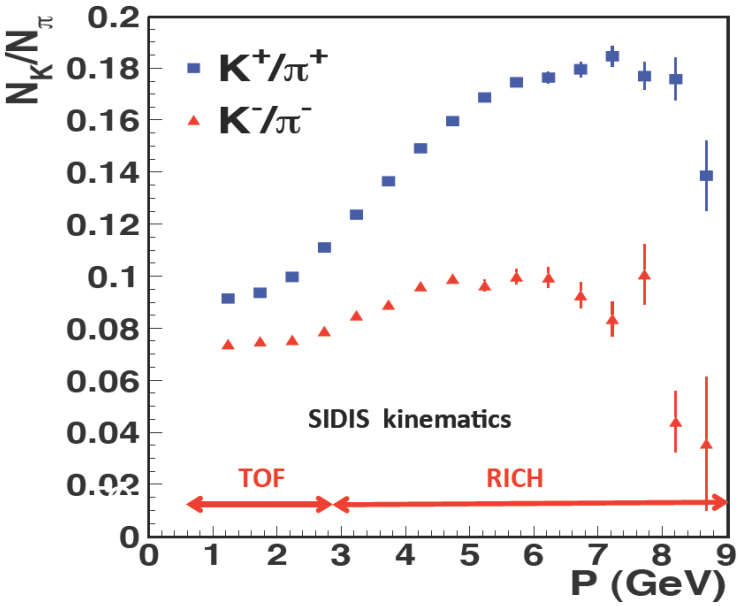


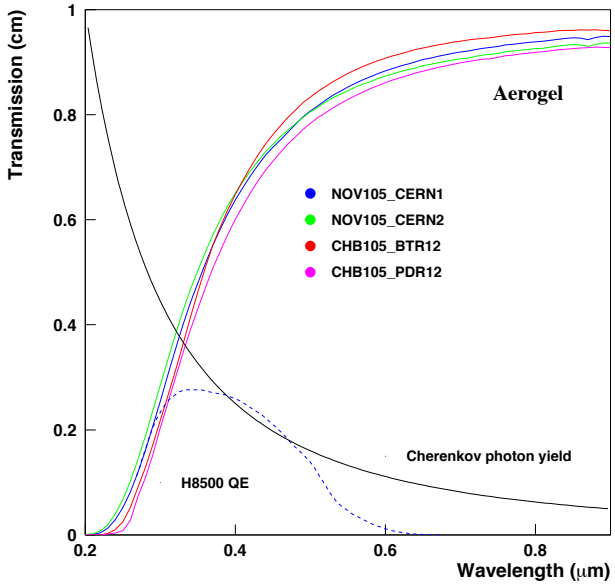
3D structure of the nucleon by
polarized deep-inelastic scattering

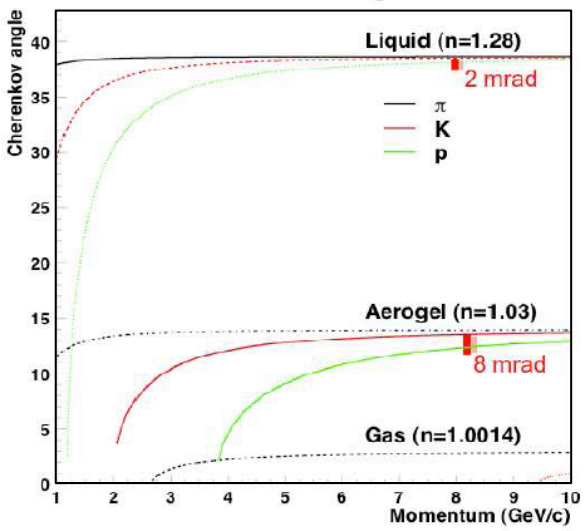
Hadron ID wanted for flavor separation

Crucial for the study of parton dynamics related to angular momentum and spin-orbit effects with flavor sensitivity.

The CLAS12 RICH Requirements





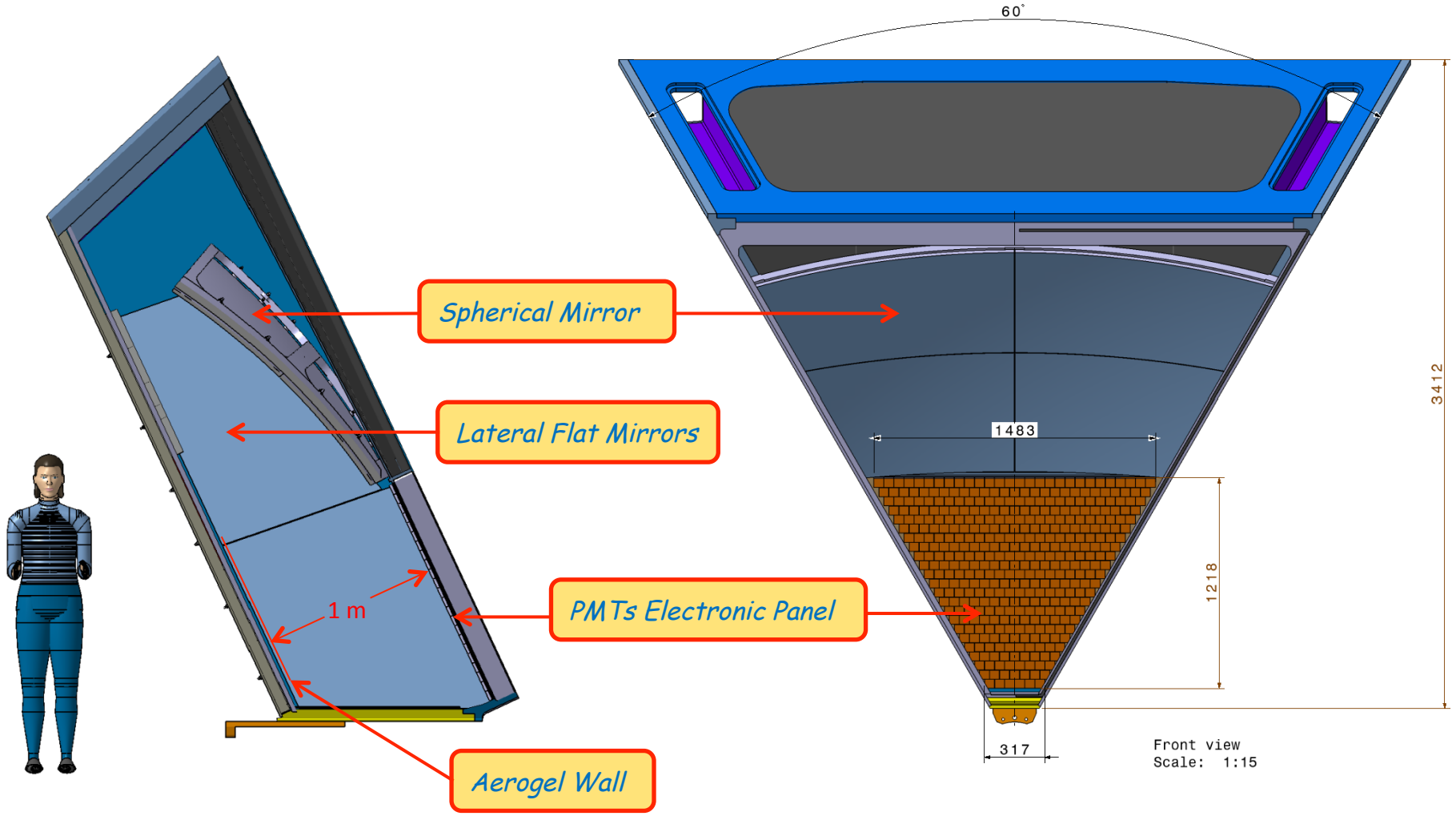


- **cover 3-8 GeV/c momentum range up to 25 degrees**
- 1:10 kaon w.r.t. pion flux → **π rejection 1:500 required**
- **Aerogel** to separate hadrons with the required rejection factors

  → collection of **visible Cherenkov light**

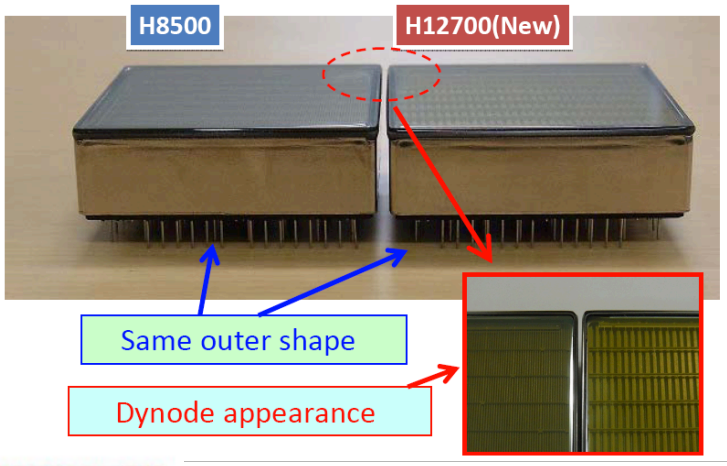
- **Use of PMTs:** challenging project, need to minimize the detector area covered with expensive photo-detectors

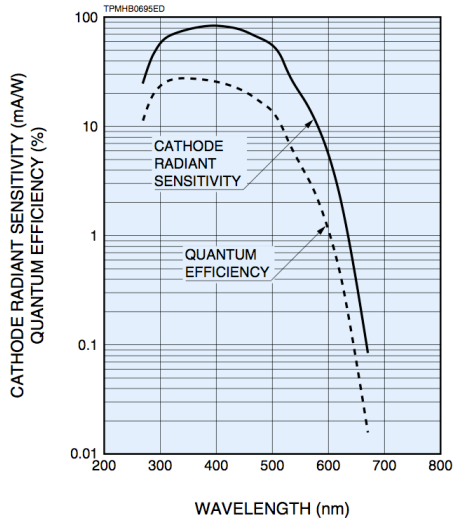
RICH Module General Assembly



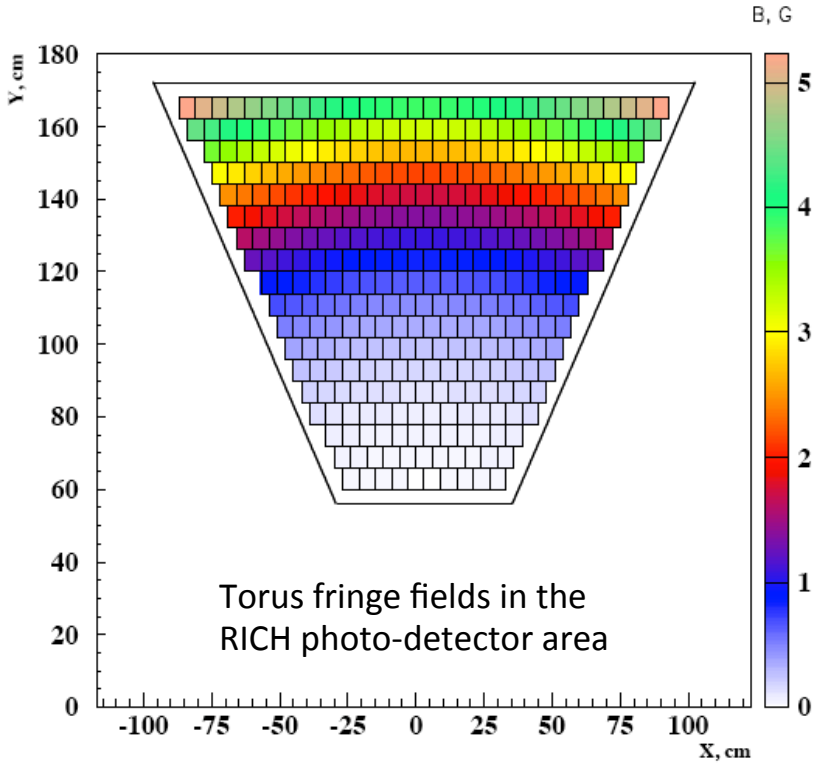
Photon Detectors: MA-PMT

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

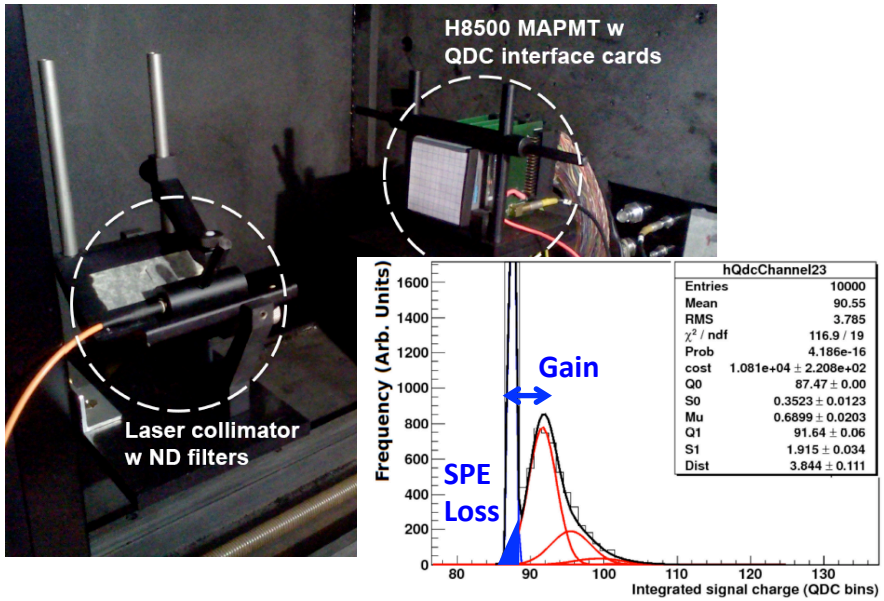




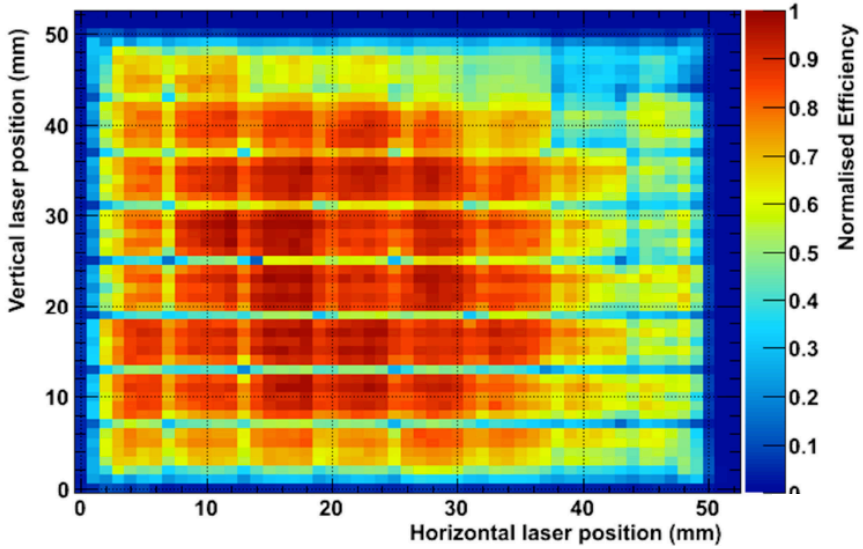
- ✓ Mature and reliable technology
- ✓ Large Area (5x5 cm^2)
- ✓ High packing density (89 %)
- ✓ 64 6x6 mm^2 pixels cost effective device
- ✓ High sensitivity on VIS towards UV light
- ✓ Fast response



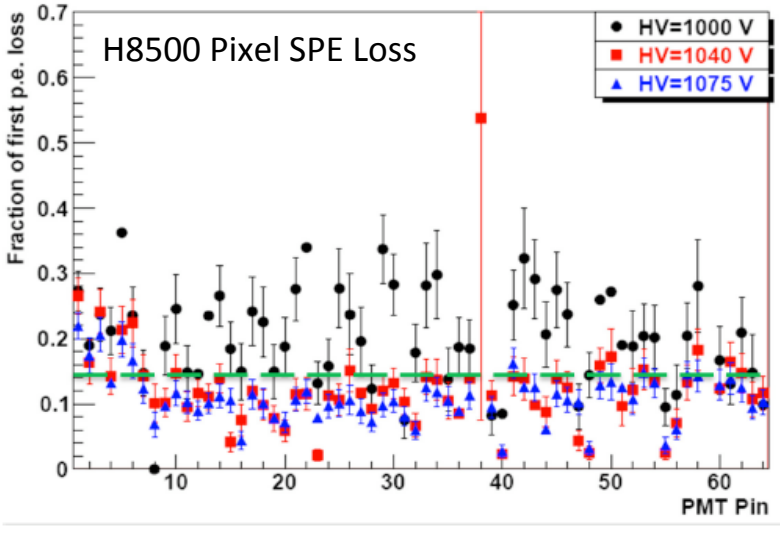
H8500 MA-PMT Characterization



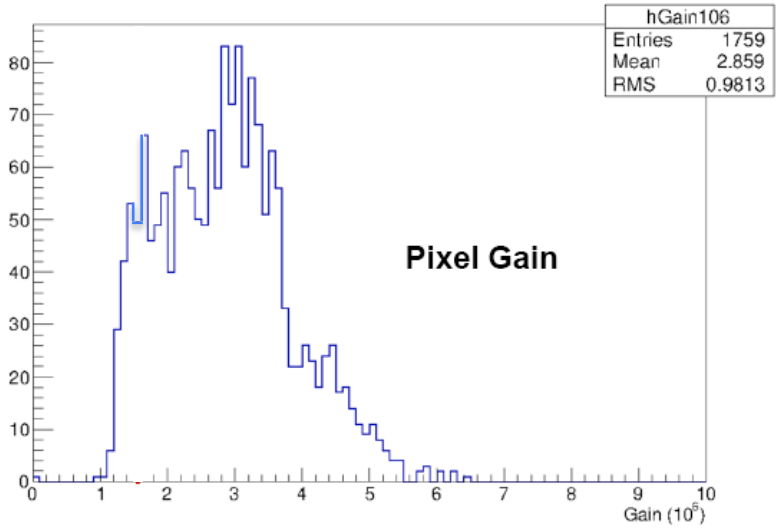
H8500



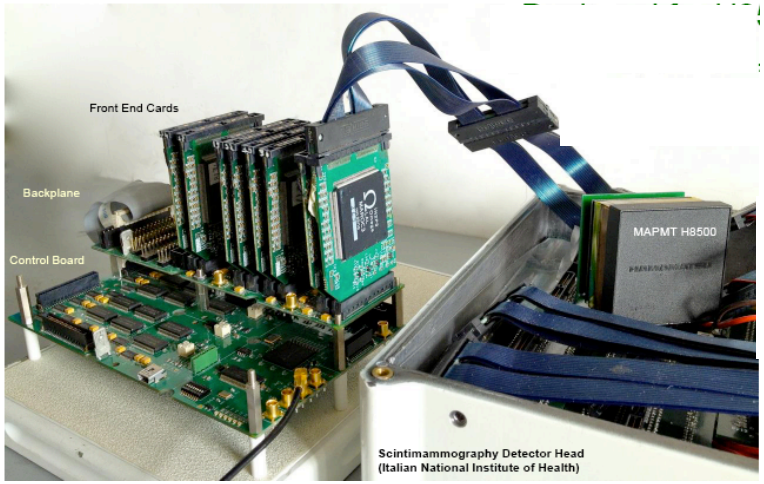
SPE loss limited to ~15% above 1040V and almost uniform over 28 MA-PMTs

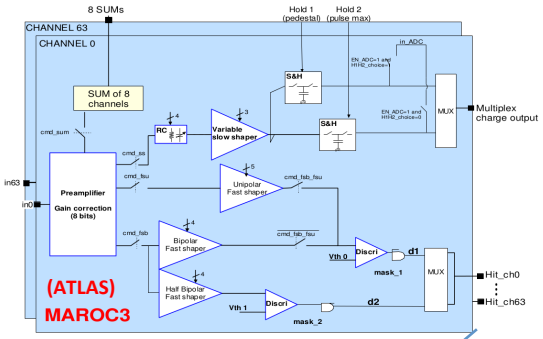


Up to 1:4 pixel gain variation can be compensated by the read-out electronics

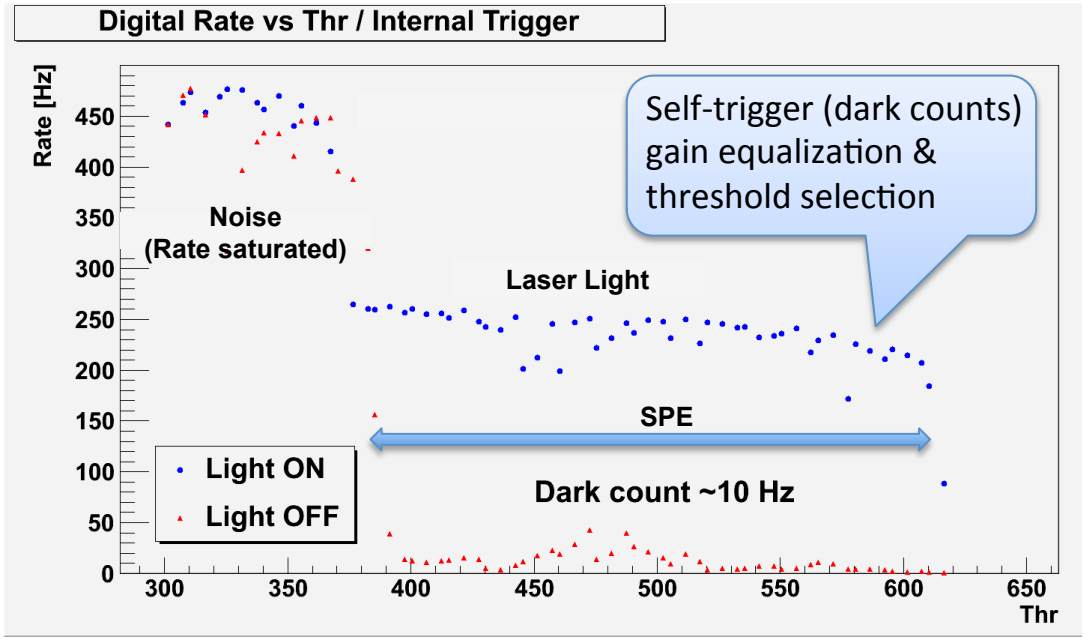


MAROC3 Front-End Electronics

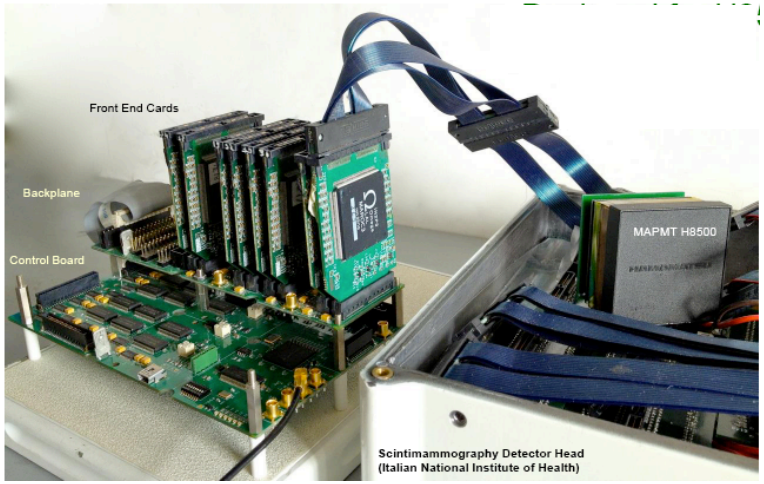


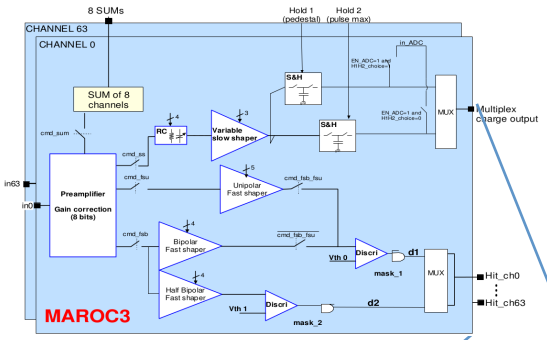


64 binary outputs with time jitter ~300 ps

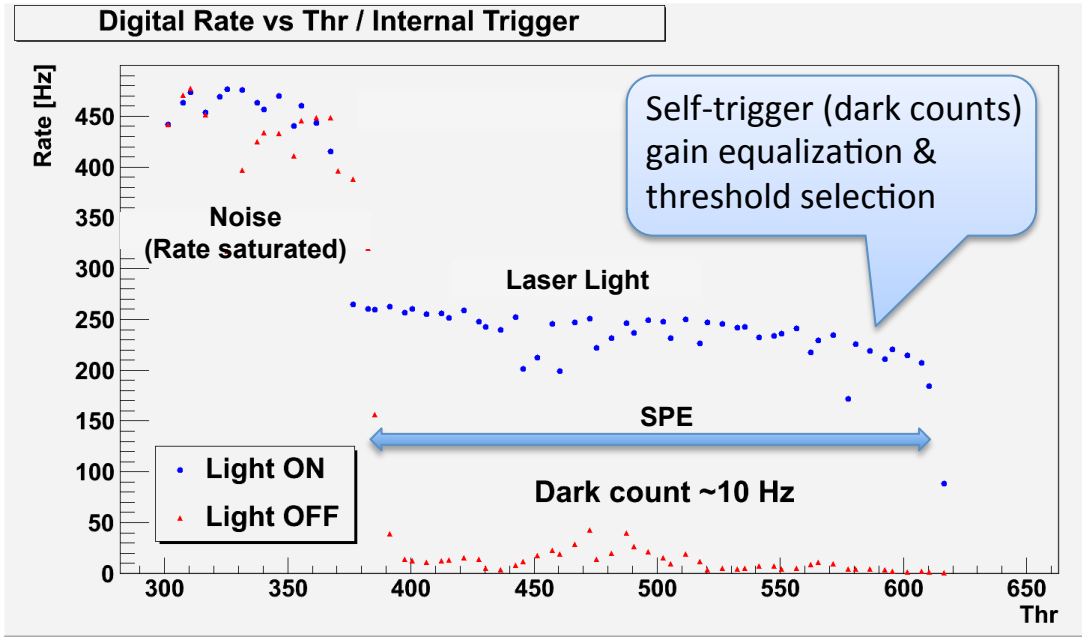


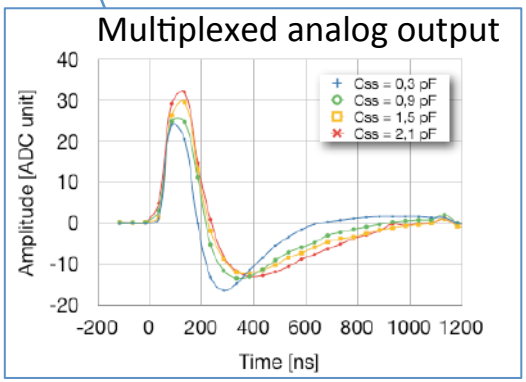
MAROC3 Front-End Electronics

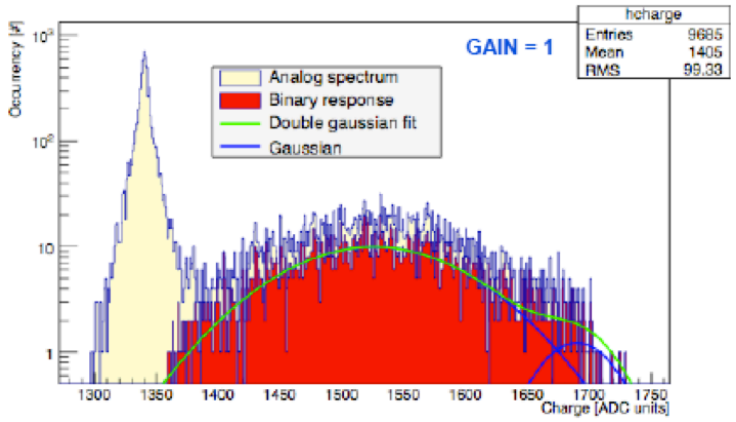




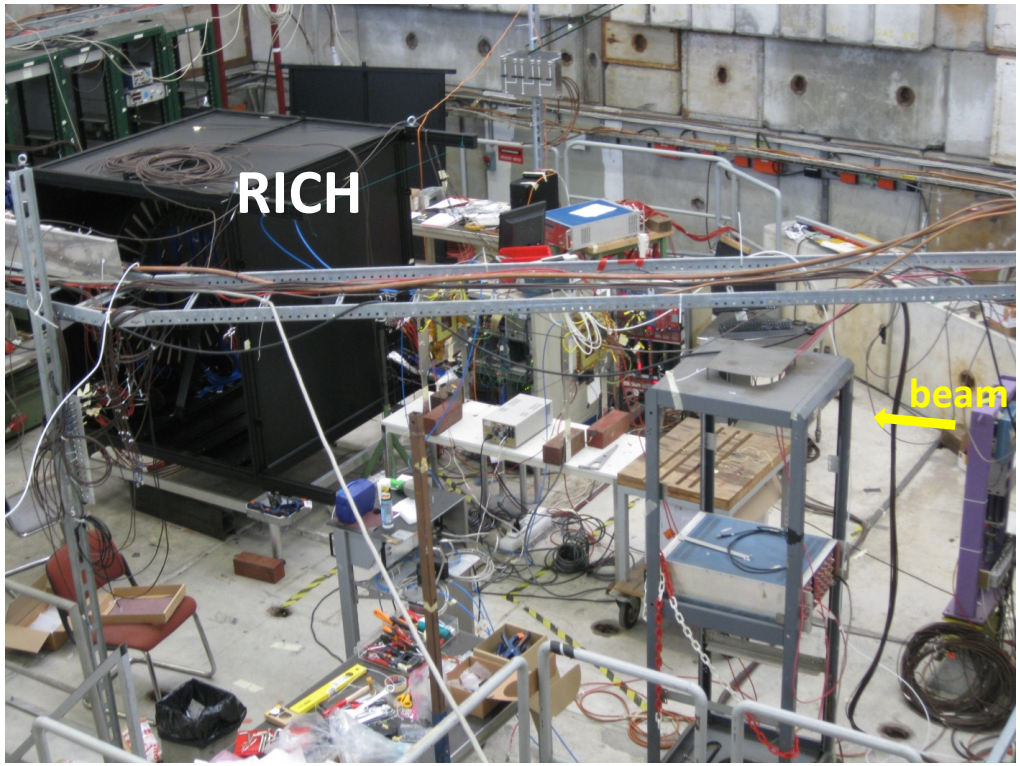
64 binary outputs with time jitter ~300 ps

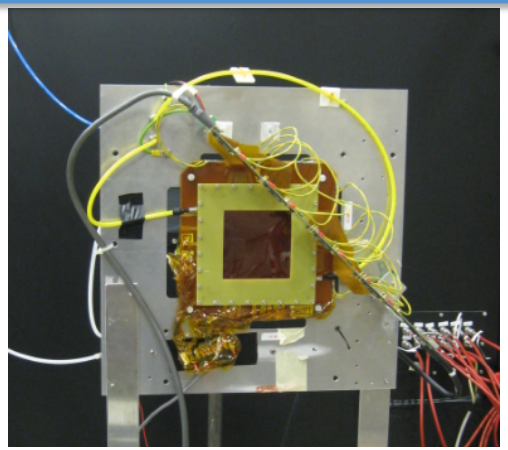






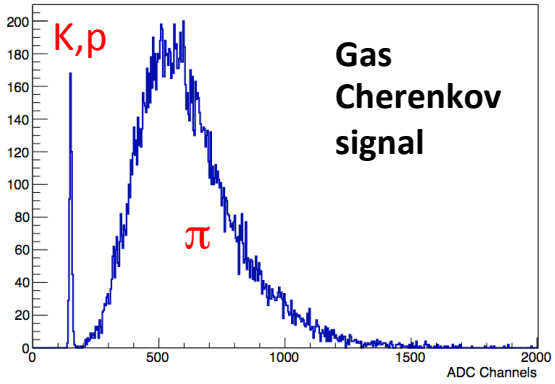
RICH Prototype at CERN-T9

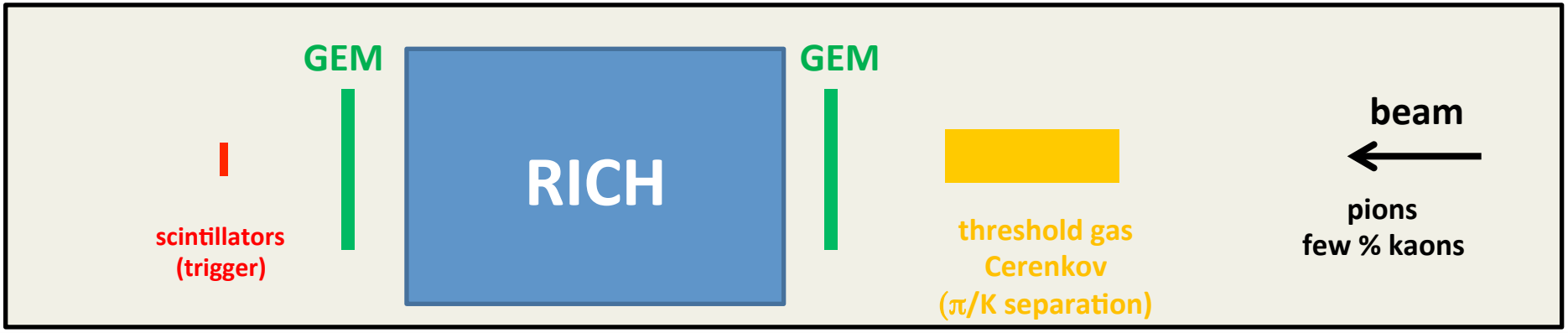




GEM chamber layout

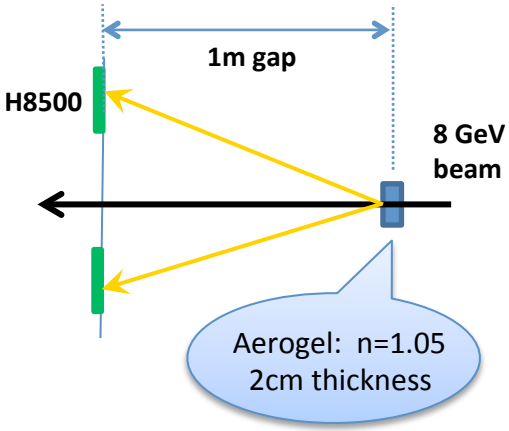
Cerenkov ADC

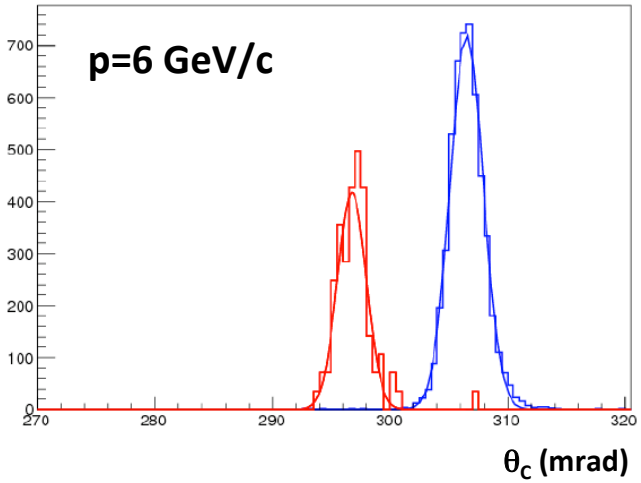


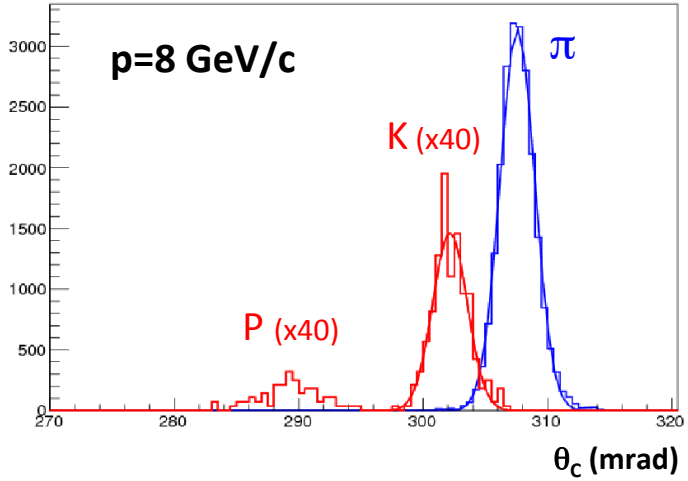


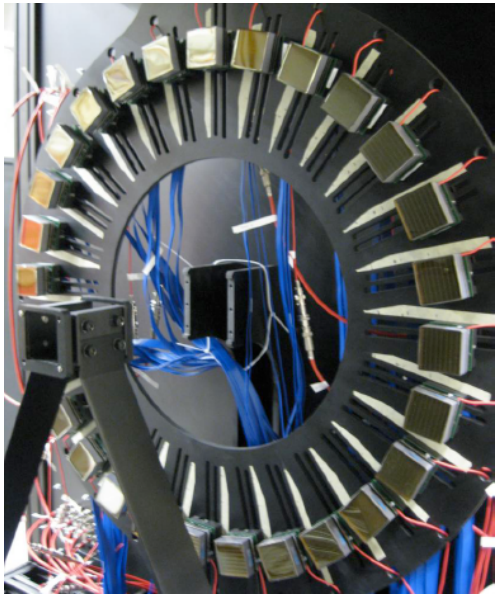
Proximity Focusing RHIC Prototype

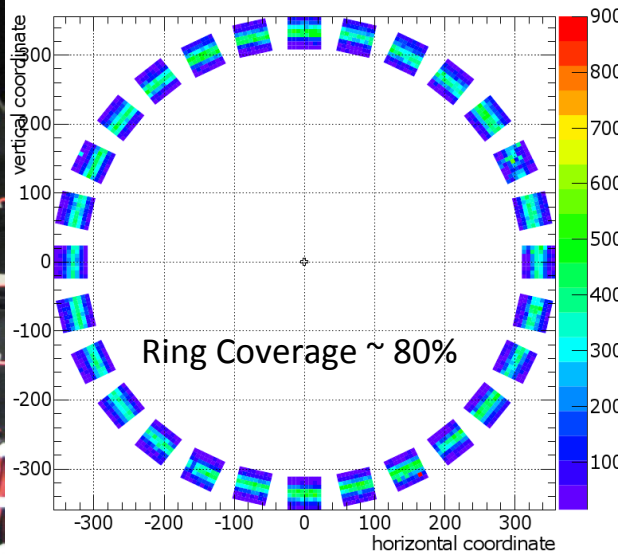
Clear hadron separation up to the CLAS12 maximum momentum











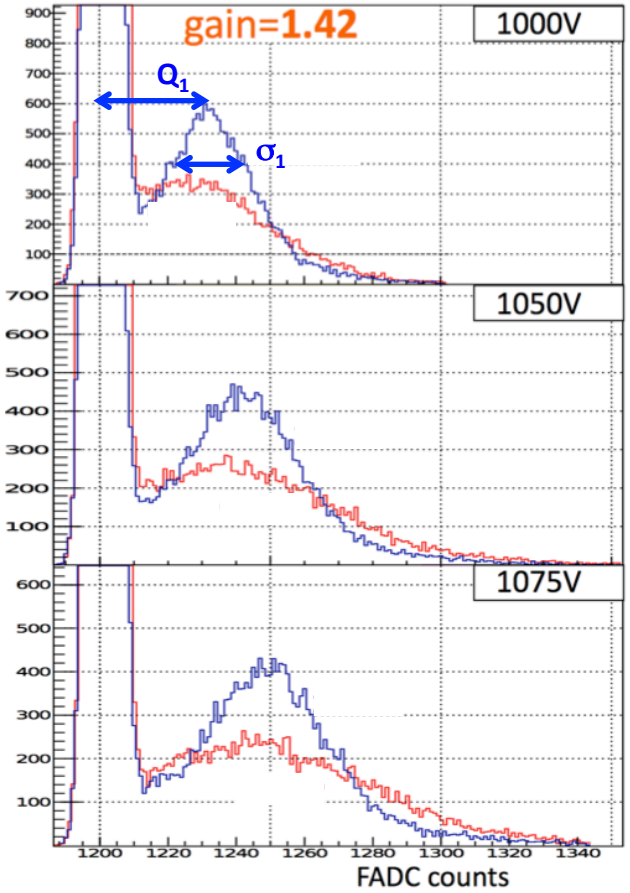
H8500 meets CLAS12 RICH requirements:

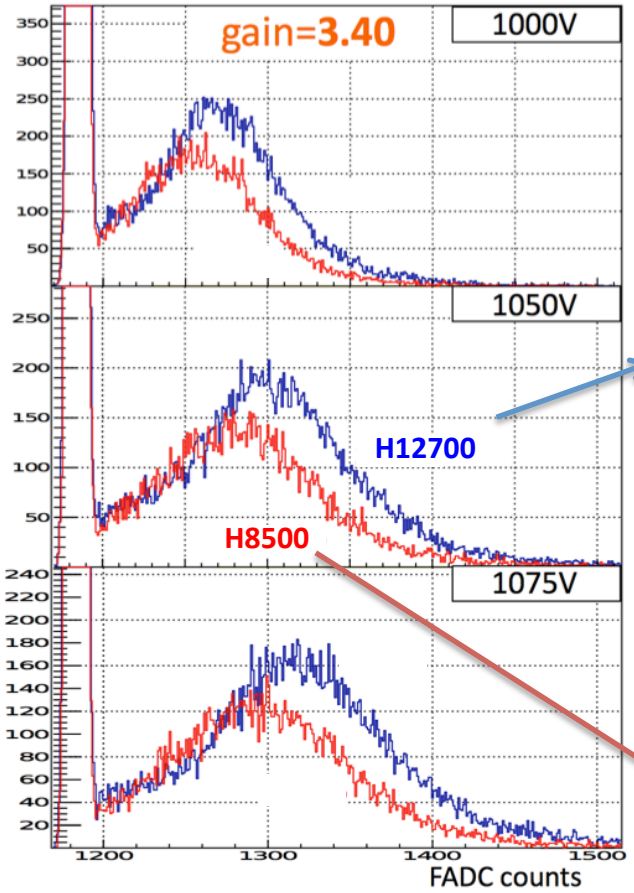
P (GeV/c)	σ_c (mrad)	σ_θ (mrad)	n_σ
6	306.5	1.41	6.9
7	306.8	1.40	4.7
8	307.6	1.40	3.9

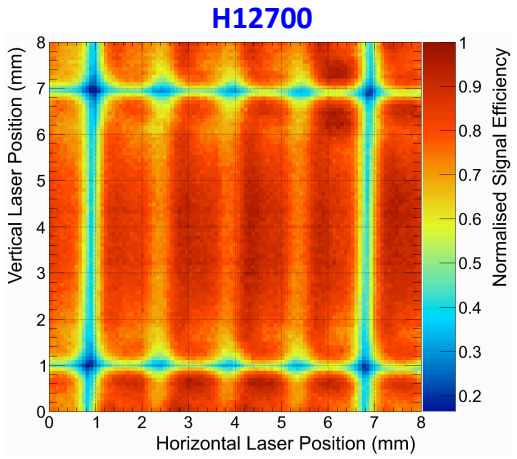
Novel H12700 MA-PMT

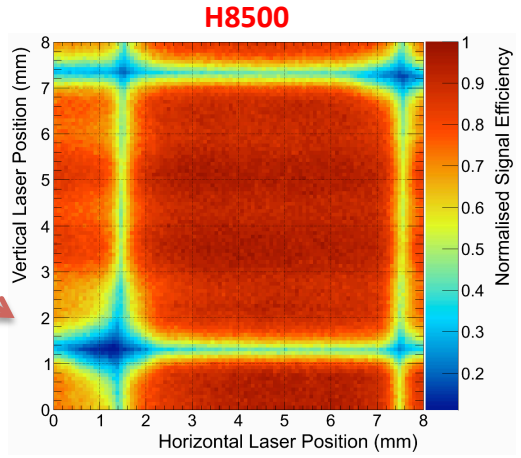
H12700
with optimized dynode structure:

- ✓ higher collection efficiency
- ✓ better SPE resolution
- ✓ enhanced cathode sensitivity
- ✓ slighter lower gain
- ✓ modest increase of dark current

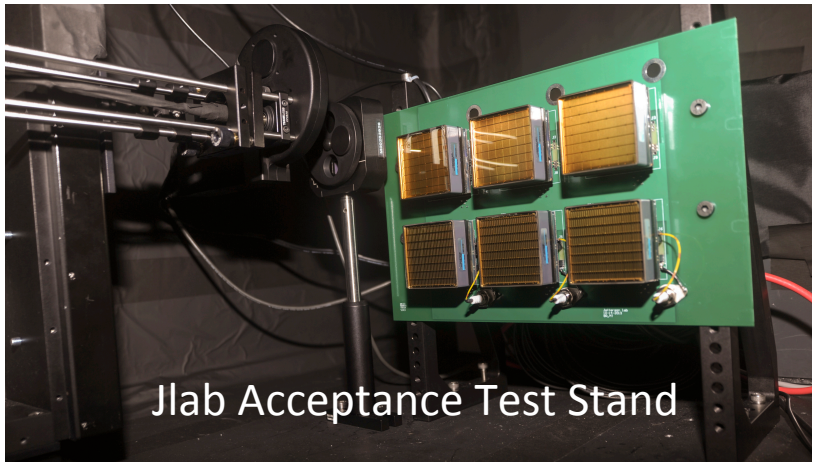




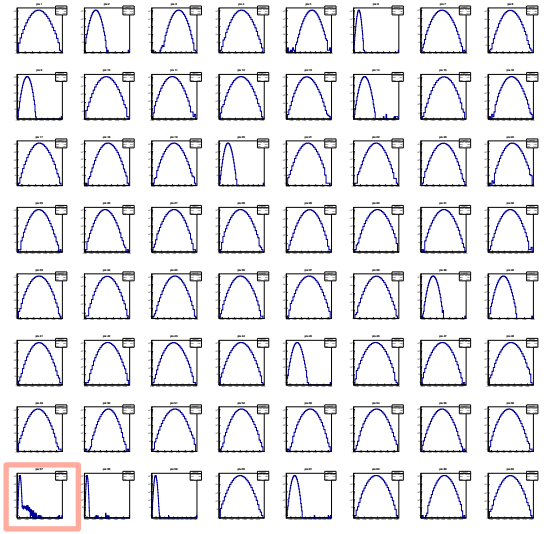


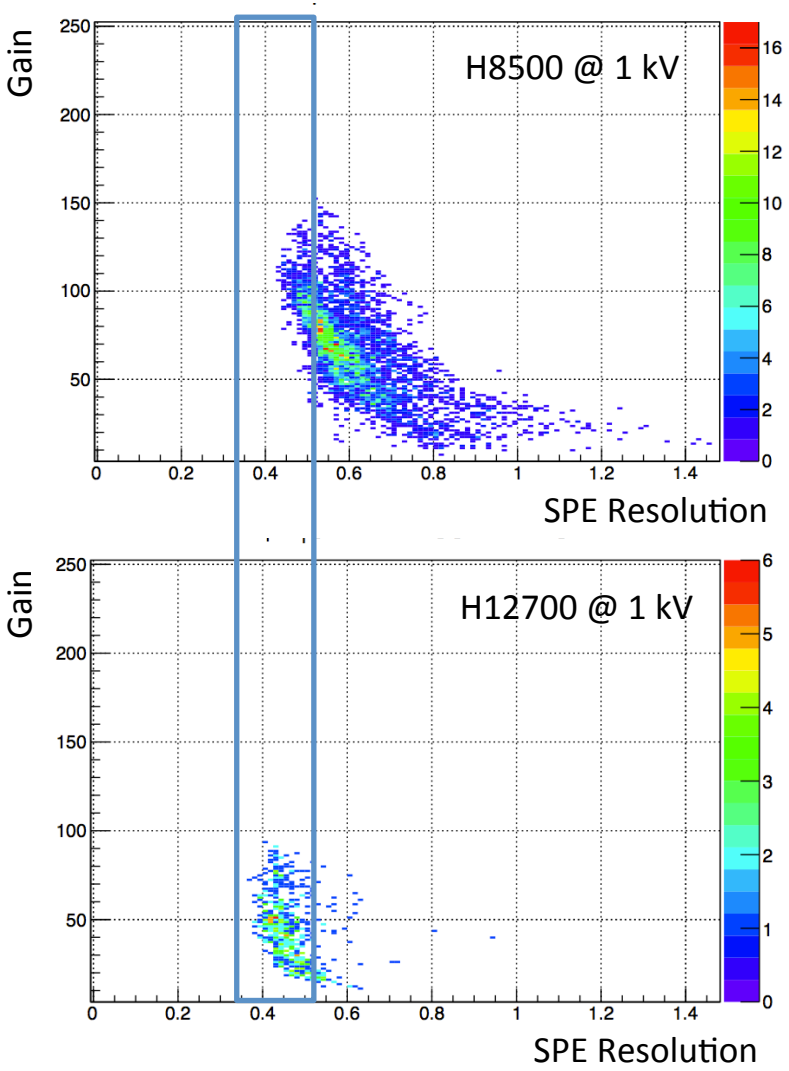


Novel H12700 MA-PMT

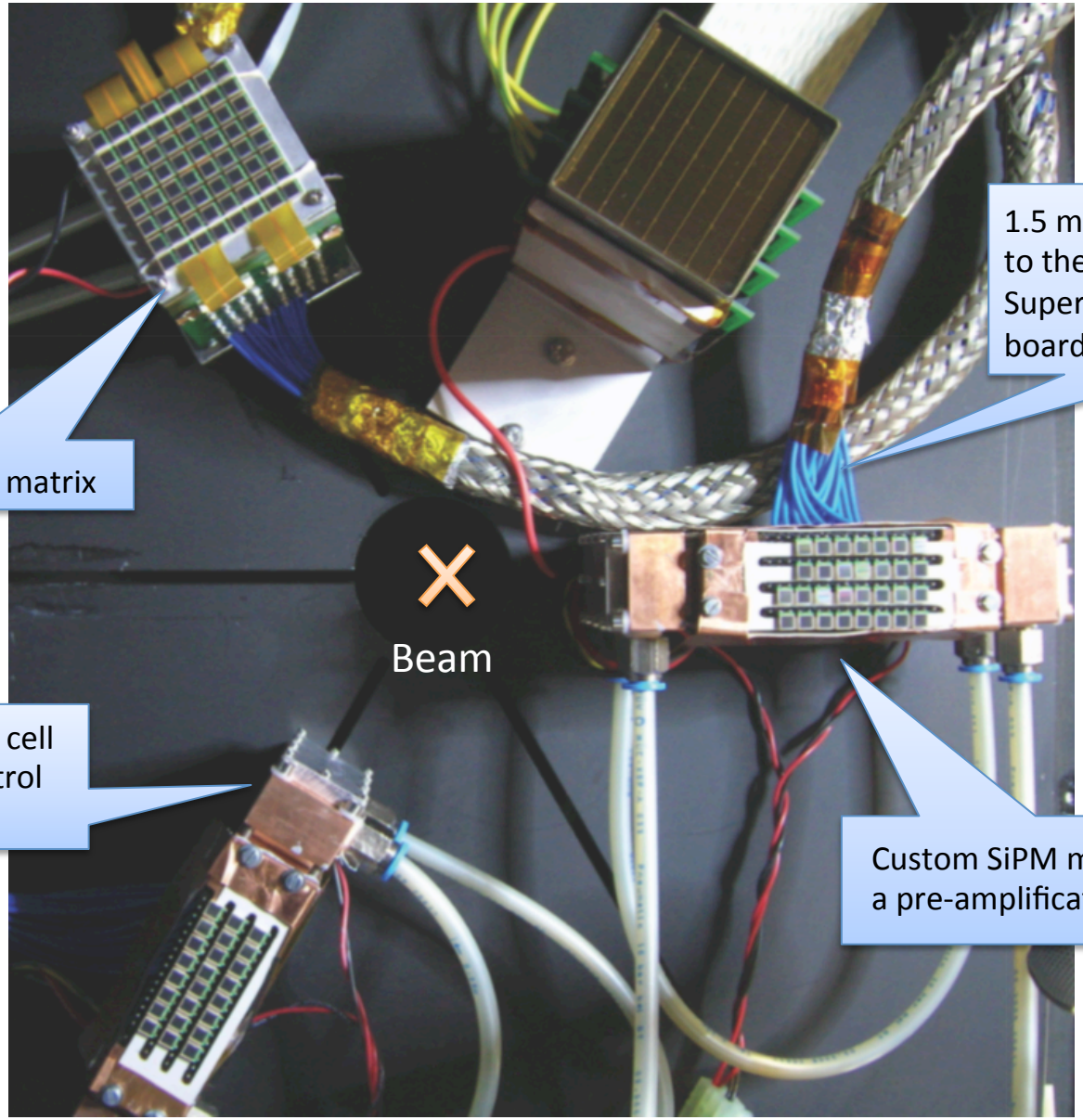


Typical higher dark current for border pixels

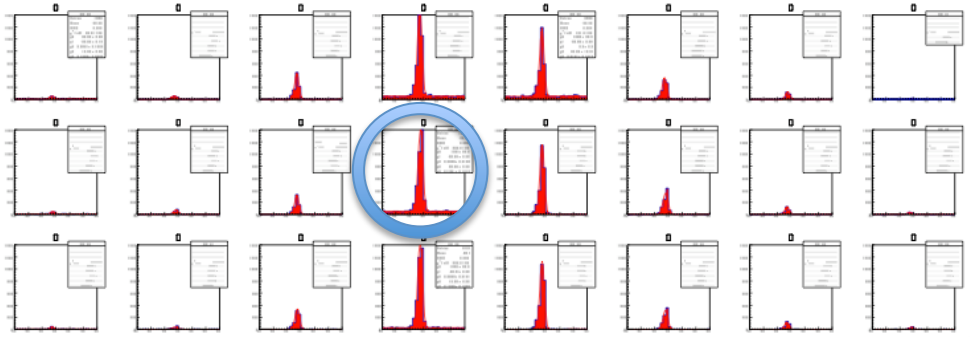




The SiPM Test Prototype



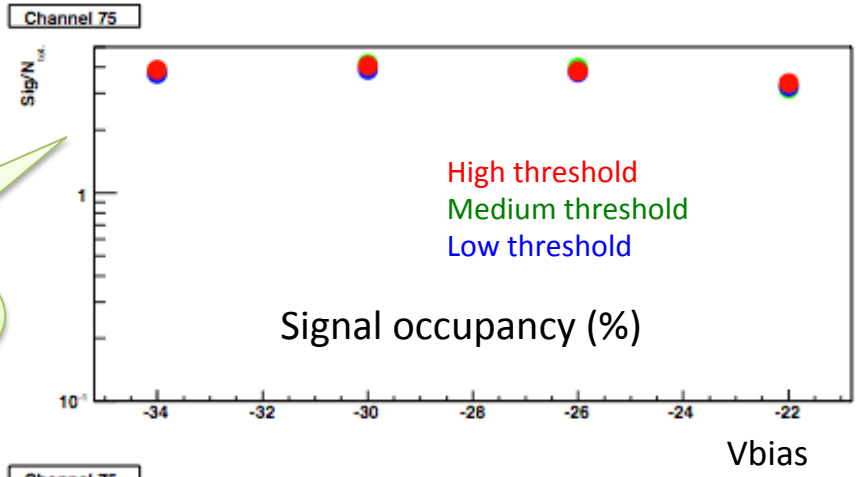
The Custom SiPM Matrix@ -25°

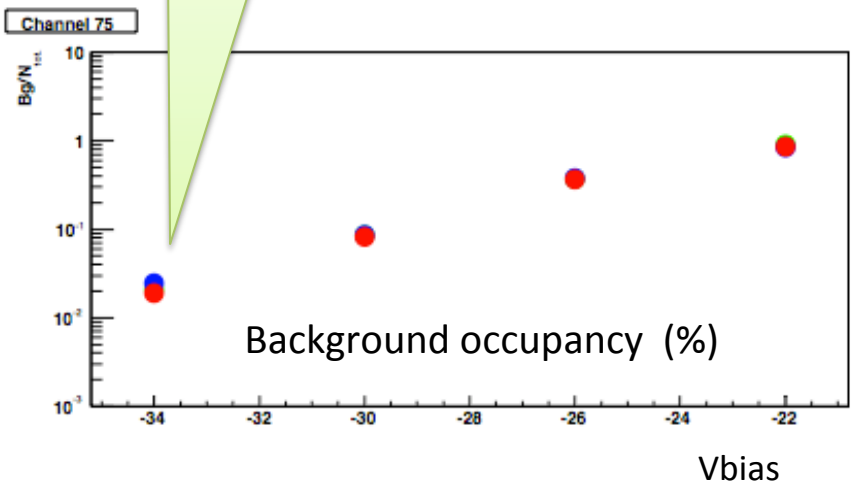


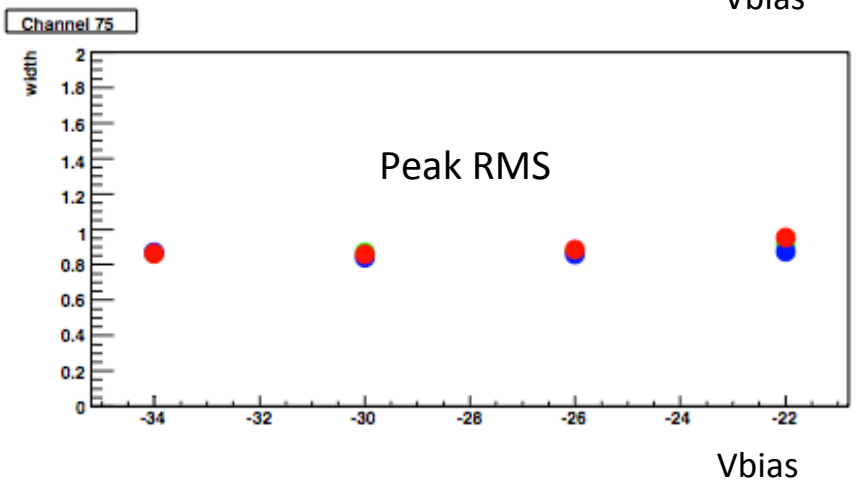
For a 12 cm radius Cherenkov cone and a 3 mm SiPM pixel, an occupancy of 4 % corresponds to about 24 p.e.

In a +/- 3 ns window
Comparable with H8500

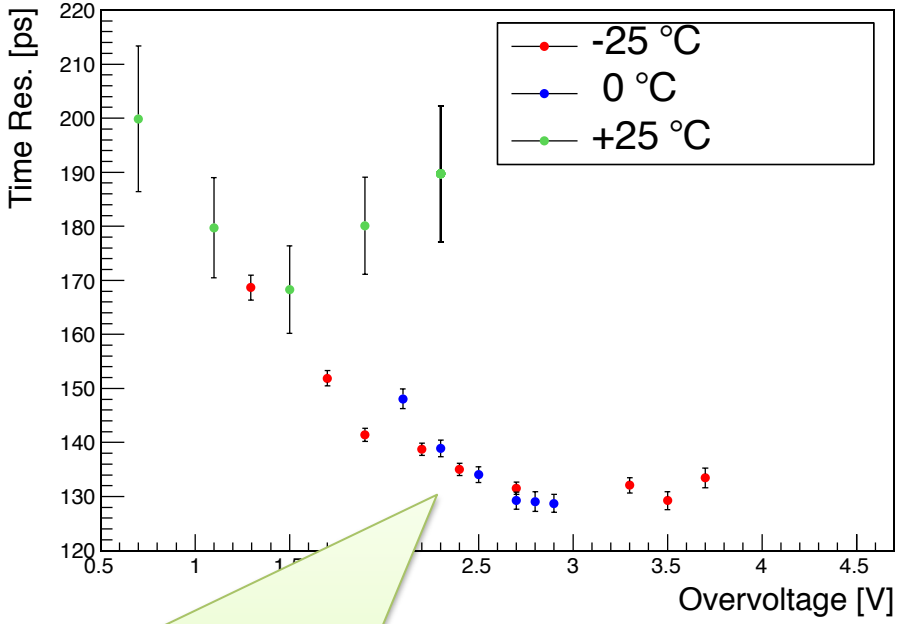
Largely insensitivity to Vbias and discriminator threshold



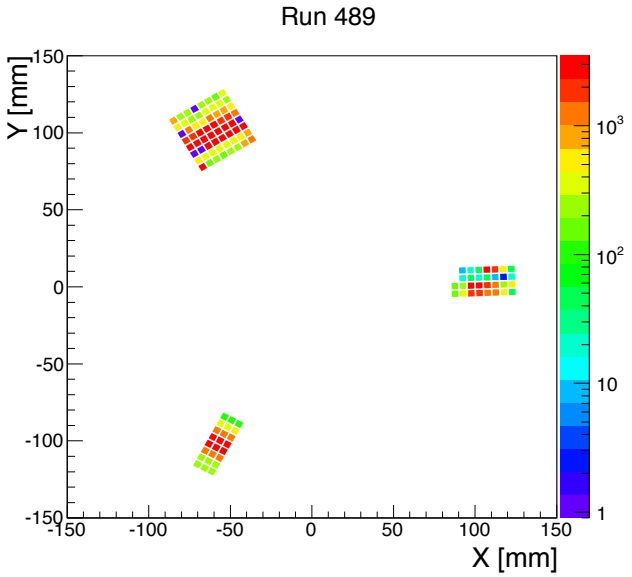




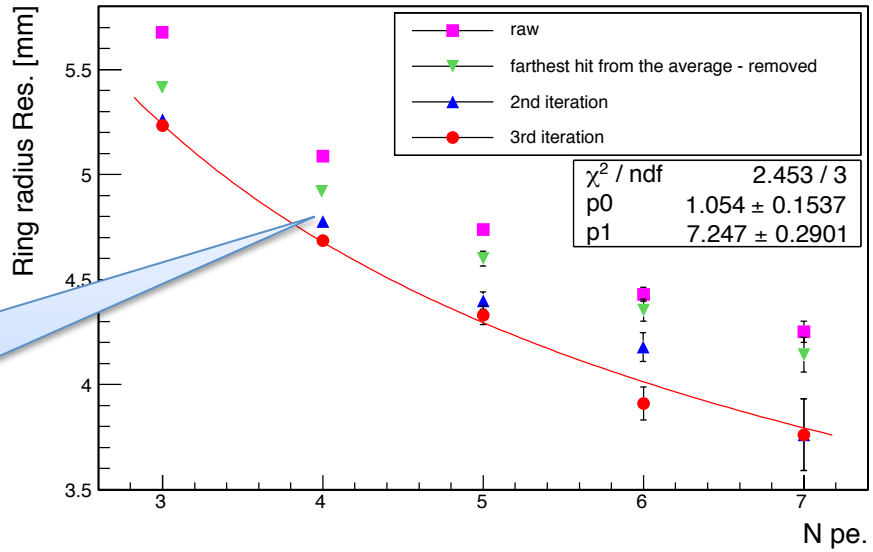
SiPM Prototype Results



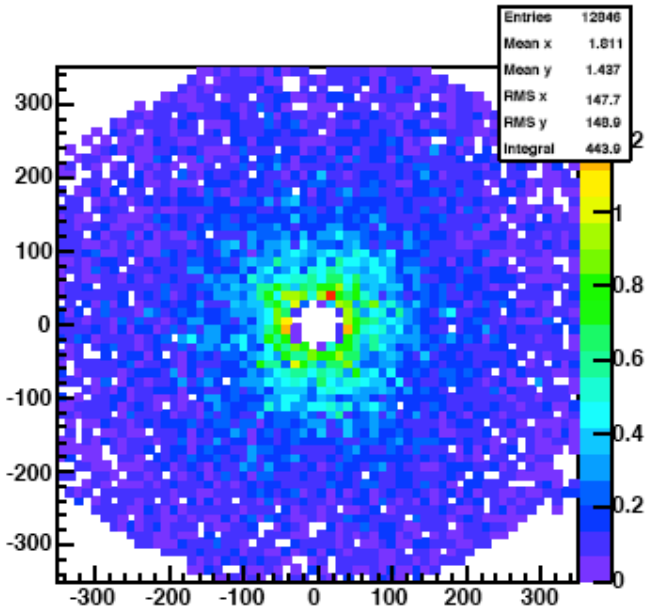
Time resolution derived from time difference of SiPM hits after removal of the single channel vs trigger offsets:
- minor residual contributions from geometry
- dominated by discriminator threshold jitter



Spatial resolution improves with SiPM hit-time analysis: iteratively reject the farthest hit in time if time difference > 0.8 ns (3 sigmas)



Neutron Irradiation Tests

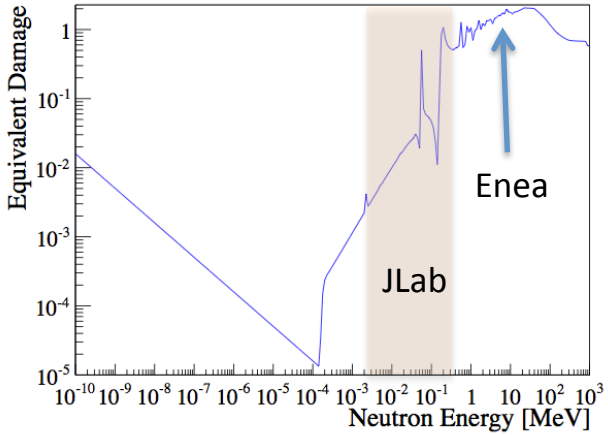


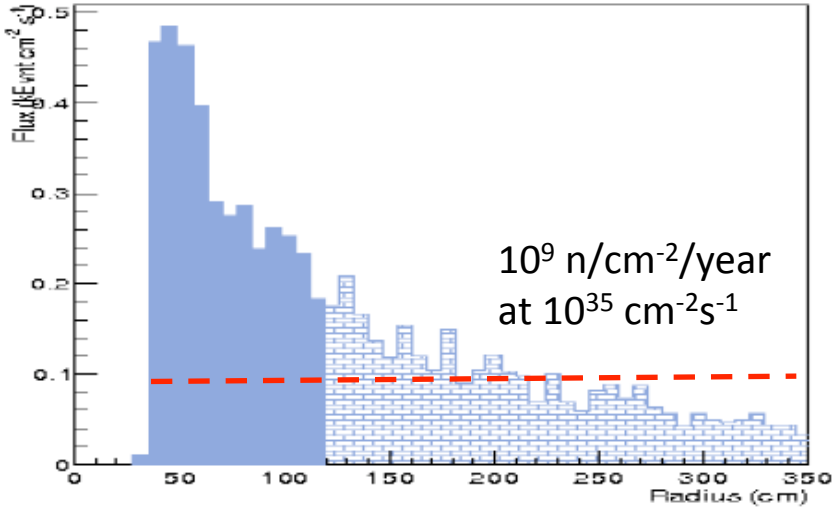
Neutrons produced isotropically through

d(230keV) t → n α

α particles measured to monitor the intensity

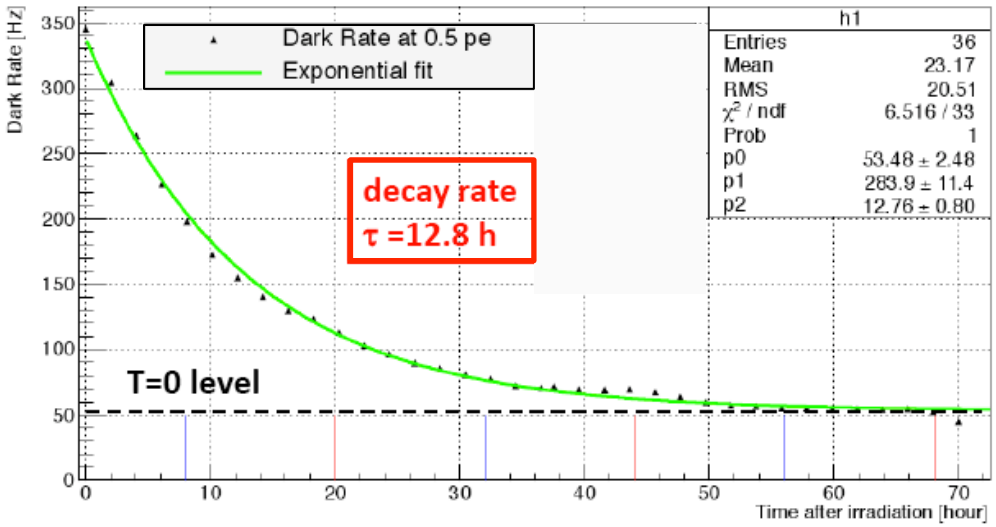
- max flux 10^{11} s^{-1} in 4π
- max neutron energy 14.6 MeV

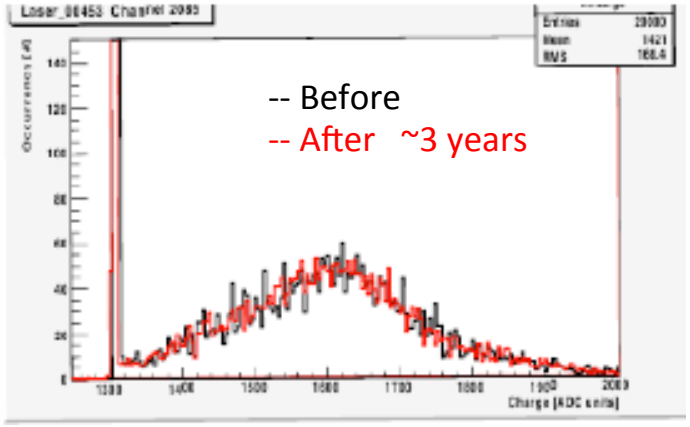




10^9 n/cm^{-2}/year
at 10^{35} cm^{-2}s^{-1}

Neutron Irradiation Tests





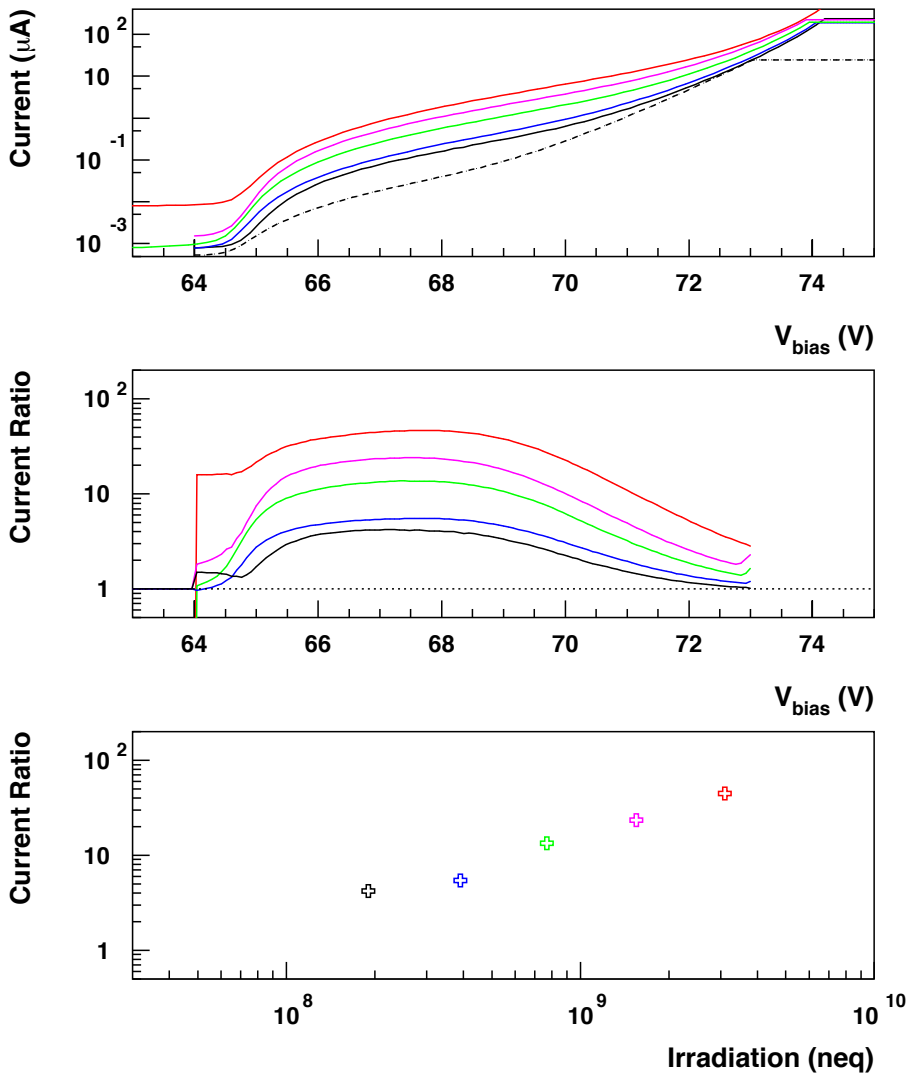
No long-term effect on MA-PMT or MAROC3, null or negligible effects expected on specific components after ~ 20 years of CLAS12

PMT window:

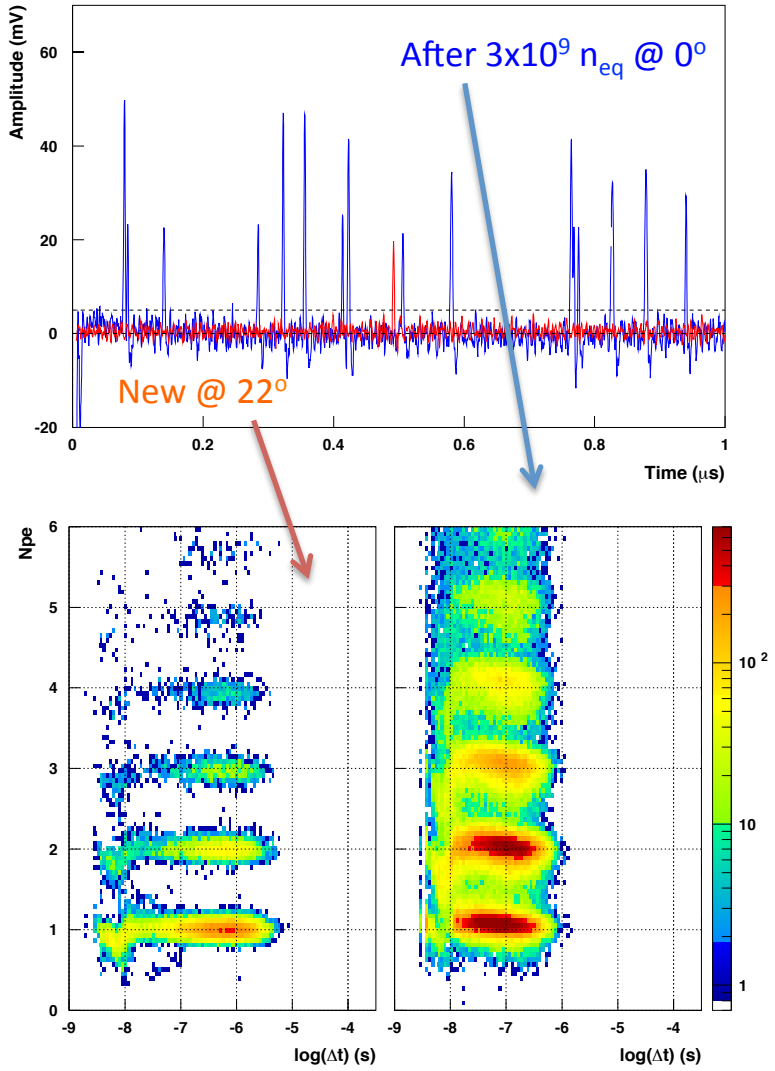
	Name	Irrad.	spread	Average	
UV	L14U2	Yes	0.3%	92.13 ± 0.12	no effect
UV	L14U	No	0.2%	92.39 ± 0.07	no effect
non-UV	L141	Yes	1.4%	89.31 ± 0.53	-2.8%
non-UV	L14	No	0.2%	92.09 ± 0.09	-2.8%
	Lucite S.	Yes	1.2%	89.37 ± 0.48	-1.3%
	Lucite L.	No	0.5%	90.65 ± 0.20	-1.3%

Neutron Irradiation Tests

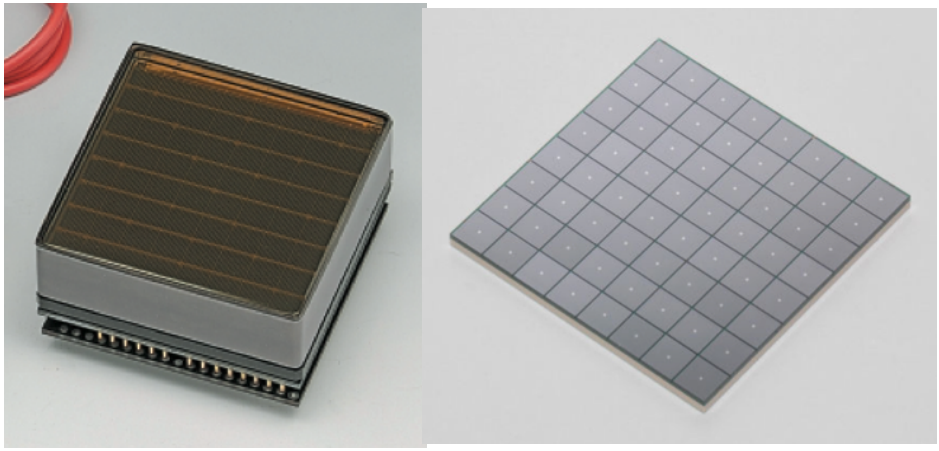
3x3 mm^2 Hamamatsu MPPC, 16μm cell



3x3 mm^2 AdvanSiD SiPM, 50μm cell

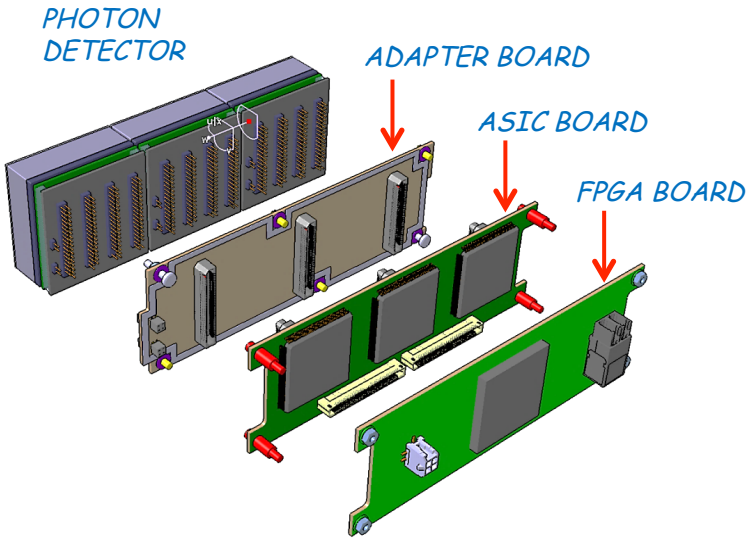


RICH Front-End Electronics

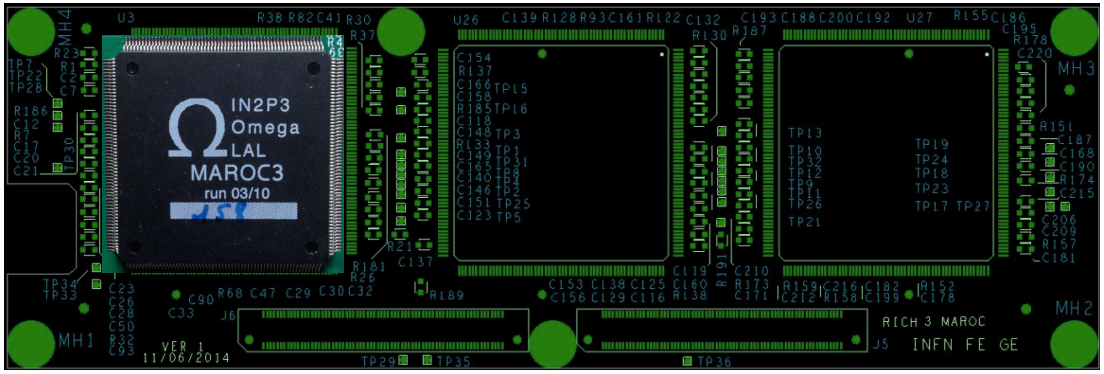


Compatible with MA-PMTs or SiPM Matrices

FPGA board



ASICs board

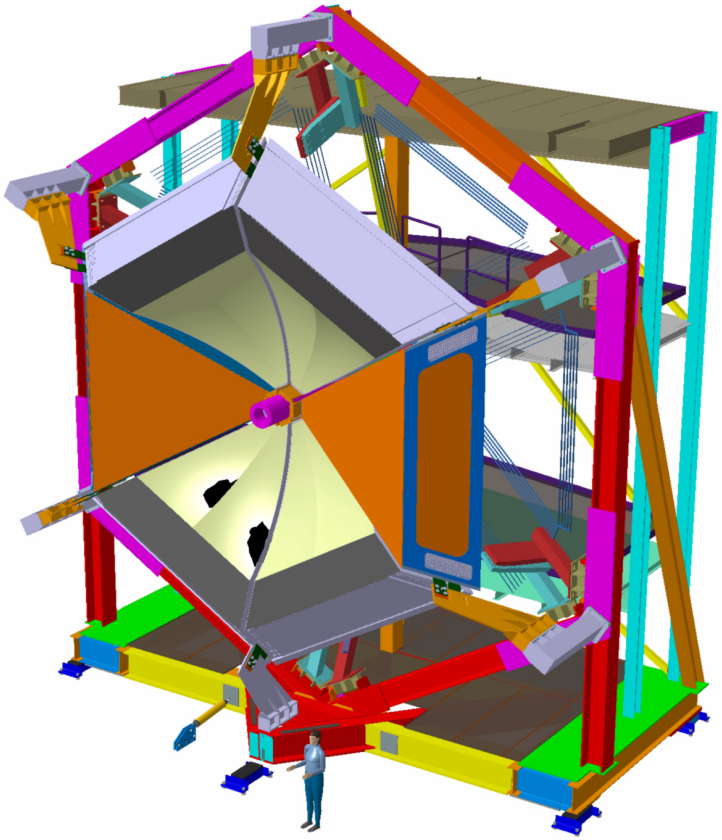


RICH Project Landscape

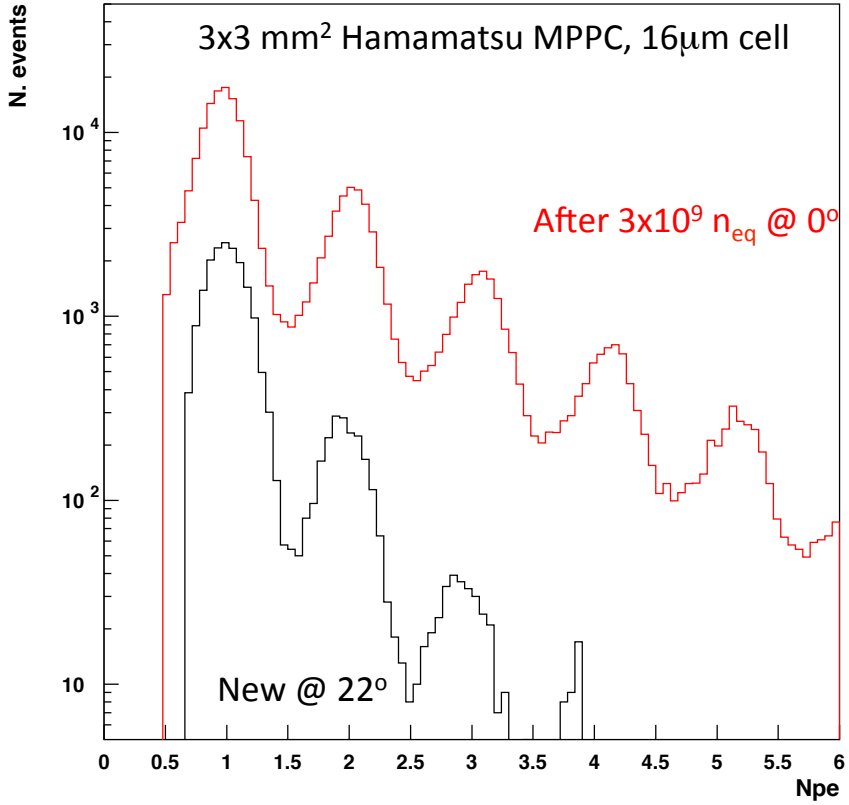
RICH goal: **4σ π/K/p separation from 3 up to 8 GeV/c**

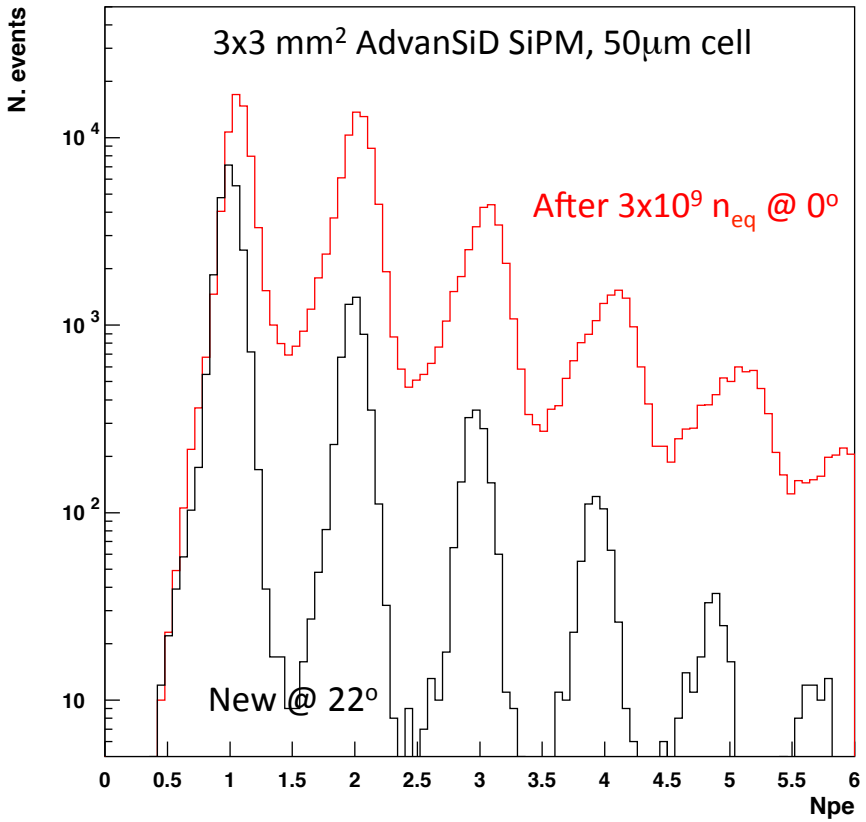
GOAL: 1st sector ready by the end of 2016

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)

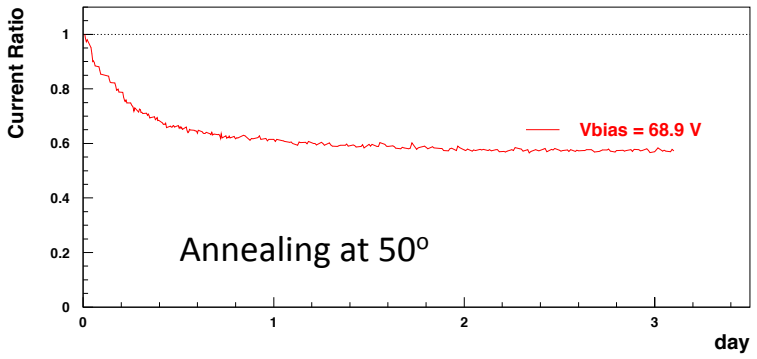


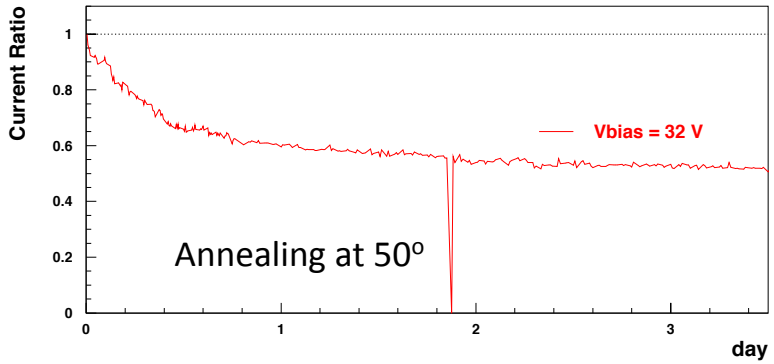
SiPM Annealing

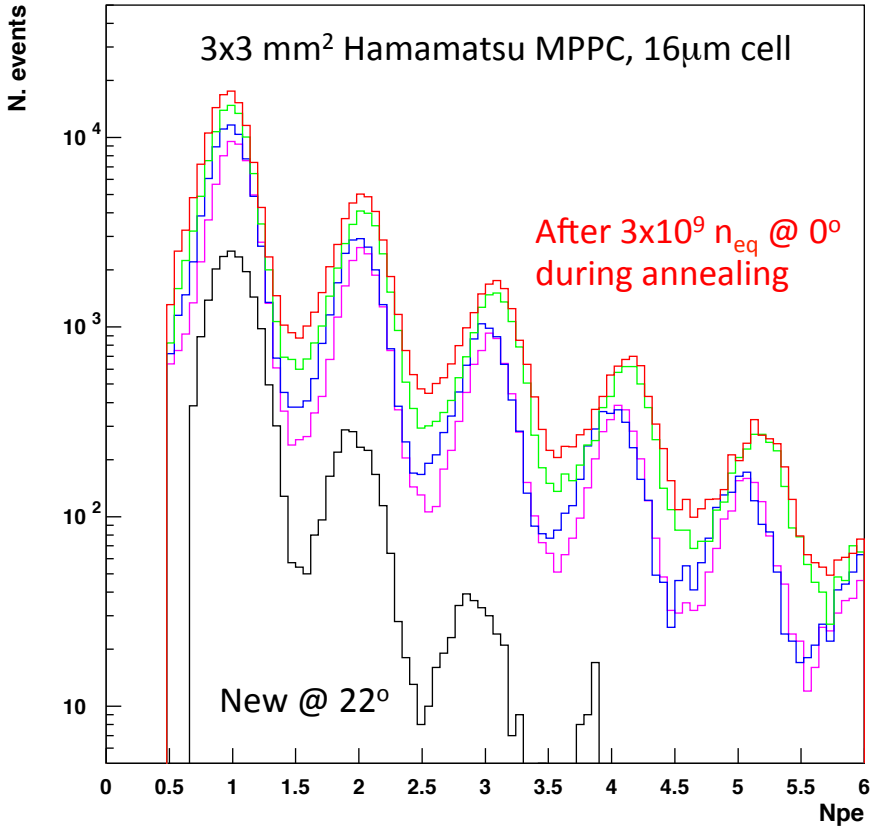


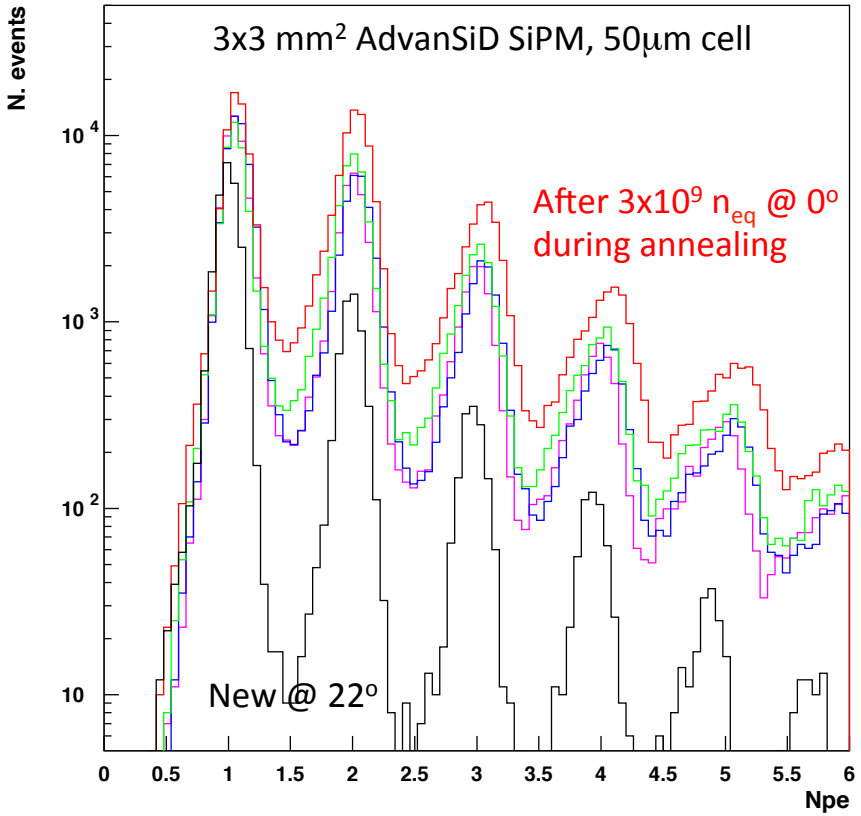


SiPM Annealing

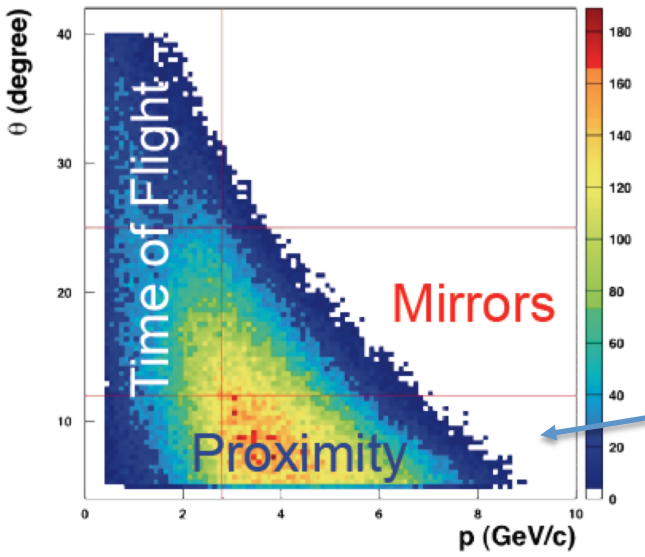




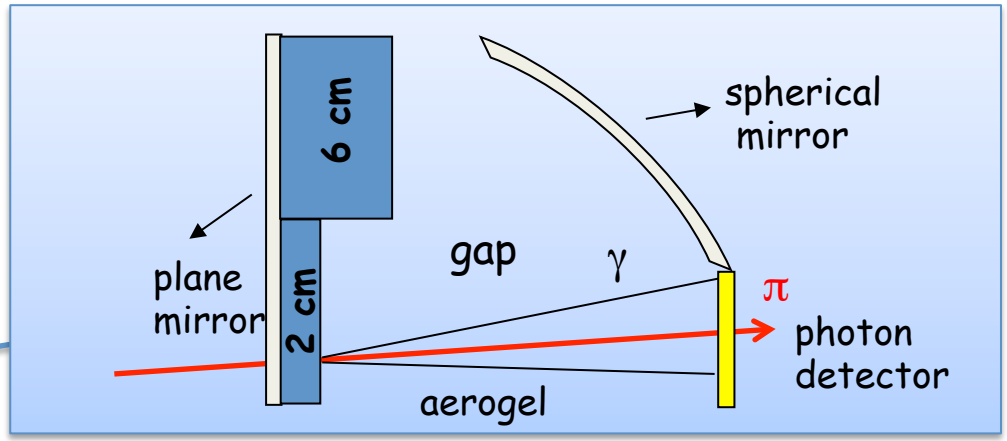


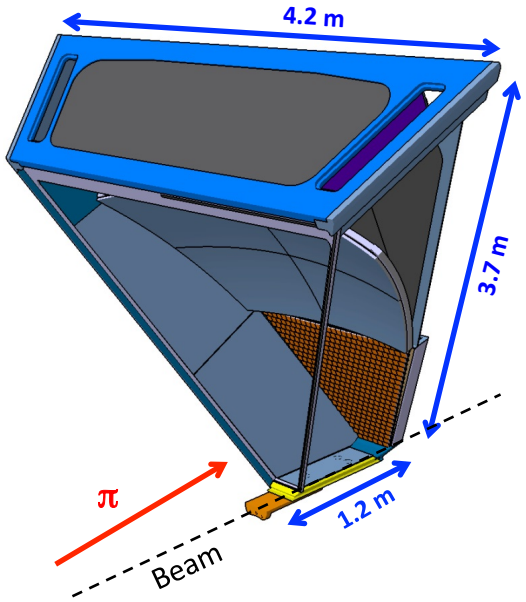


The Hybrid Optics Design

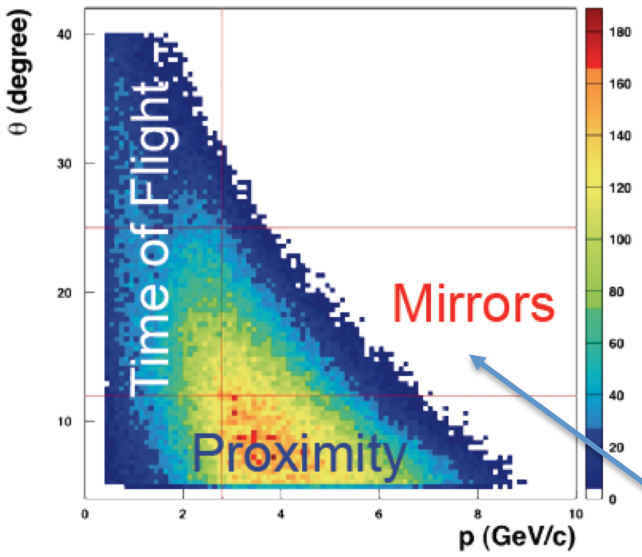


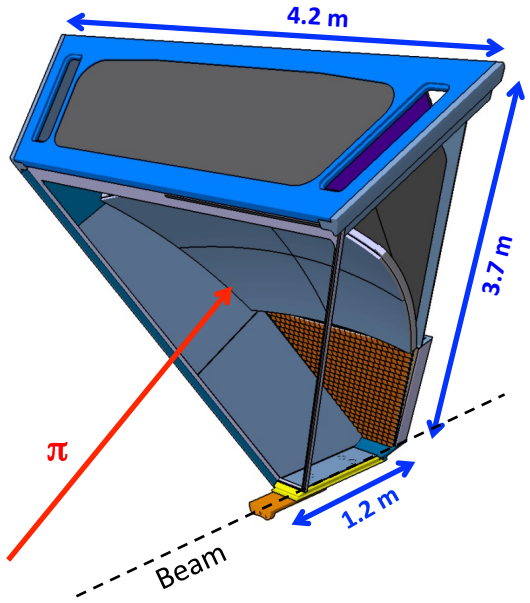
Direct rings and best performance for high momentum particles



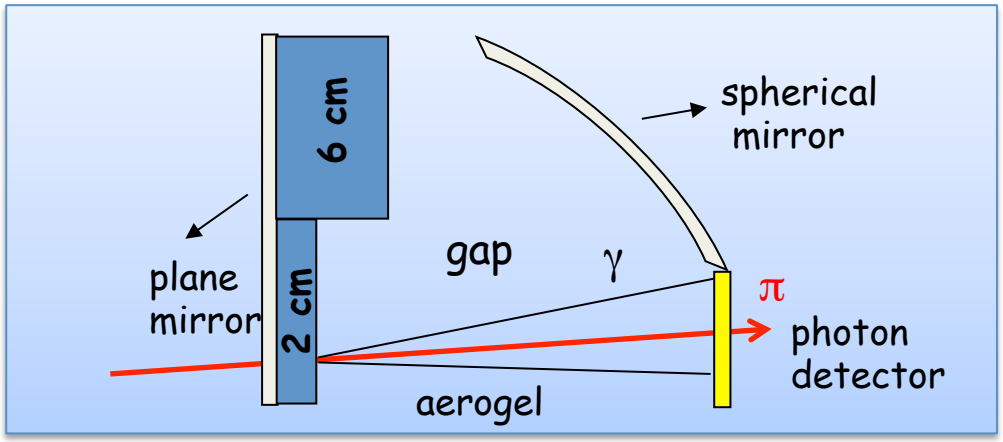


The Hybrid Optics Design

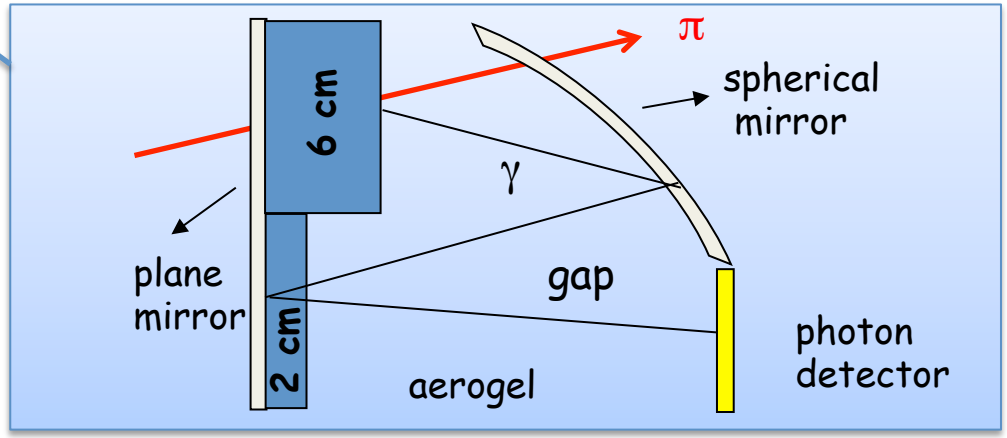




Direct rings and best performance for high momentum particles

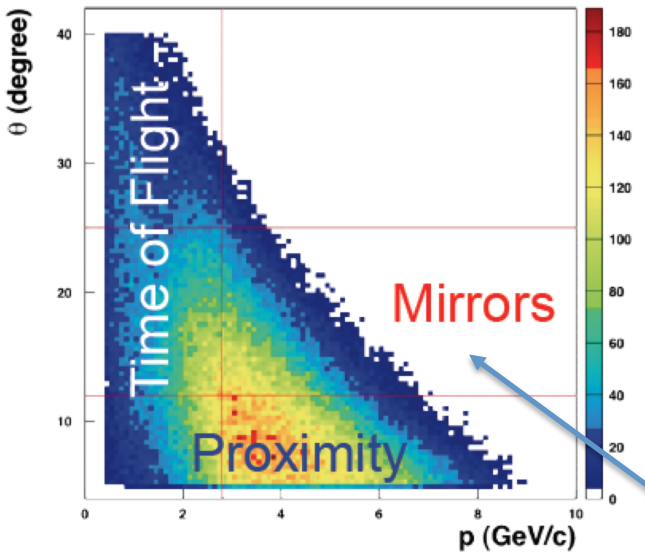


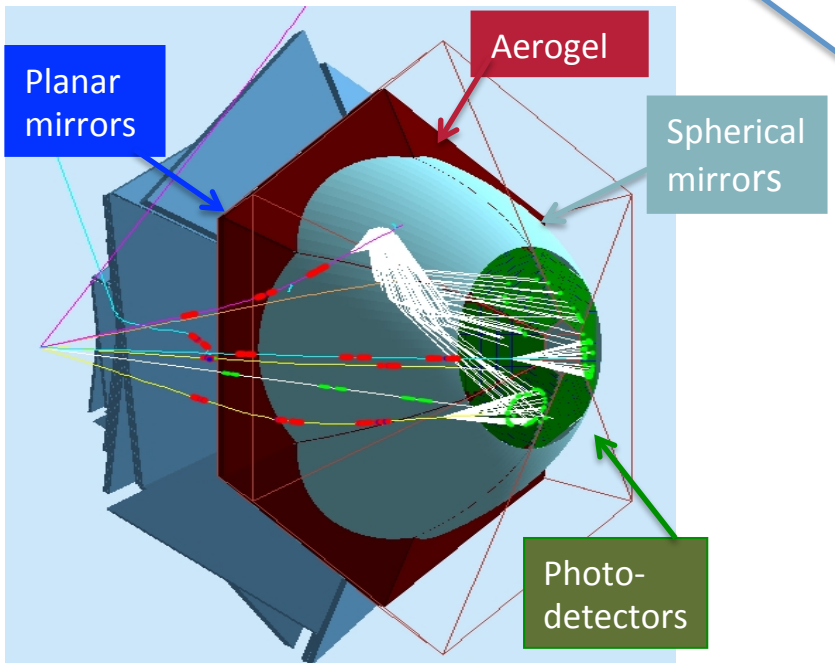
Reflected rings for less demanding low momentum particles



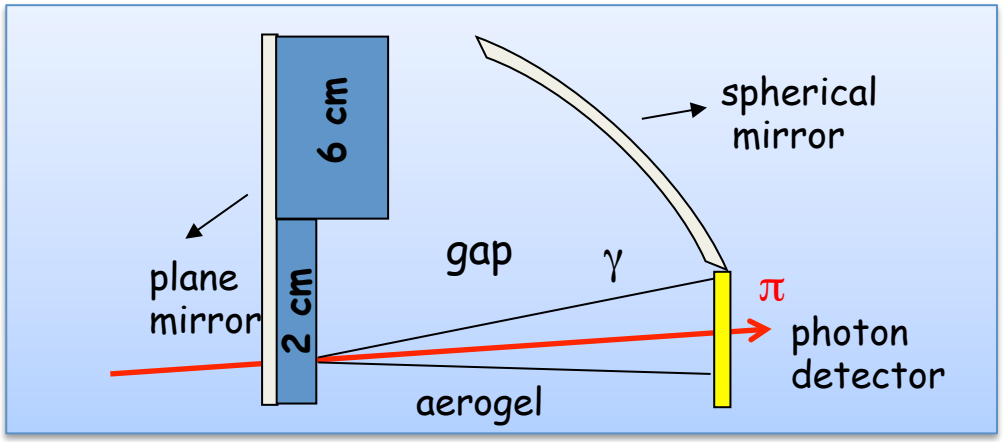
- Minimize active area (cost) to about 1 m^2
- Material budget concentrated where TOF is less effective
- Focalizing mirrors allow thick radiator for good light yield
- Time resolution < 1 ns to distinguish direct and reflected patterns

The Hybrid Optics Design

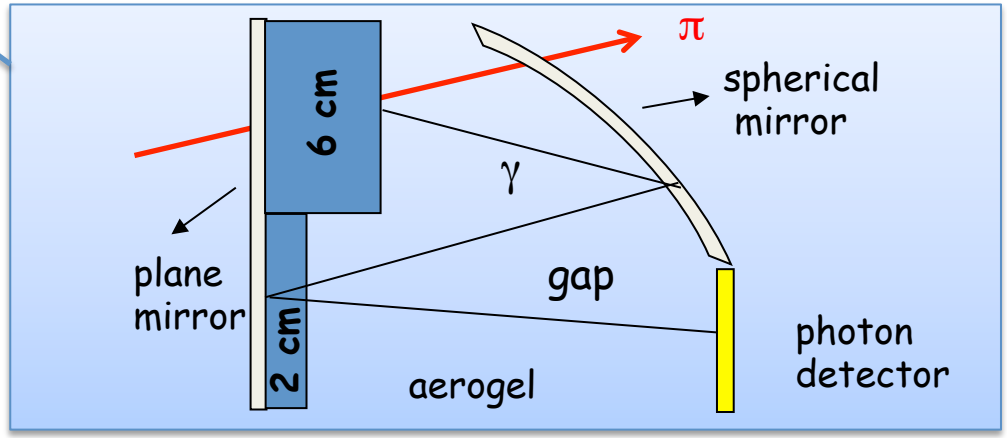




Direct rings and best performance for high momentum particles

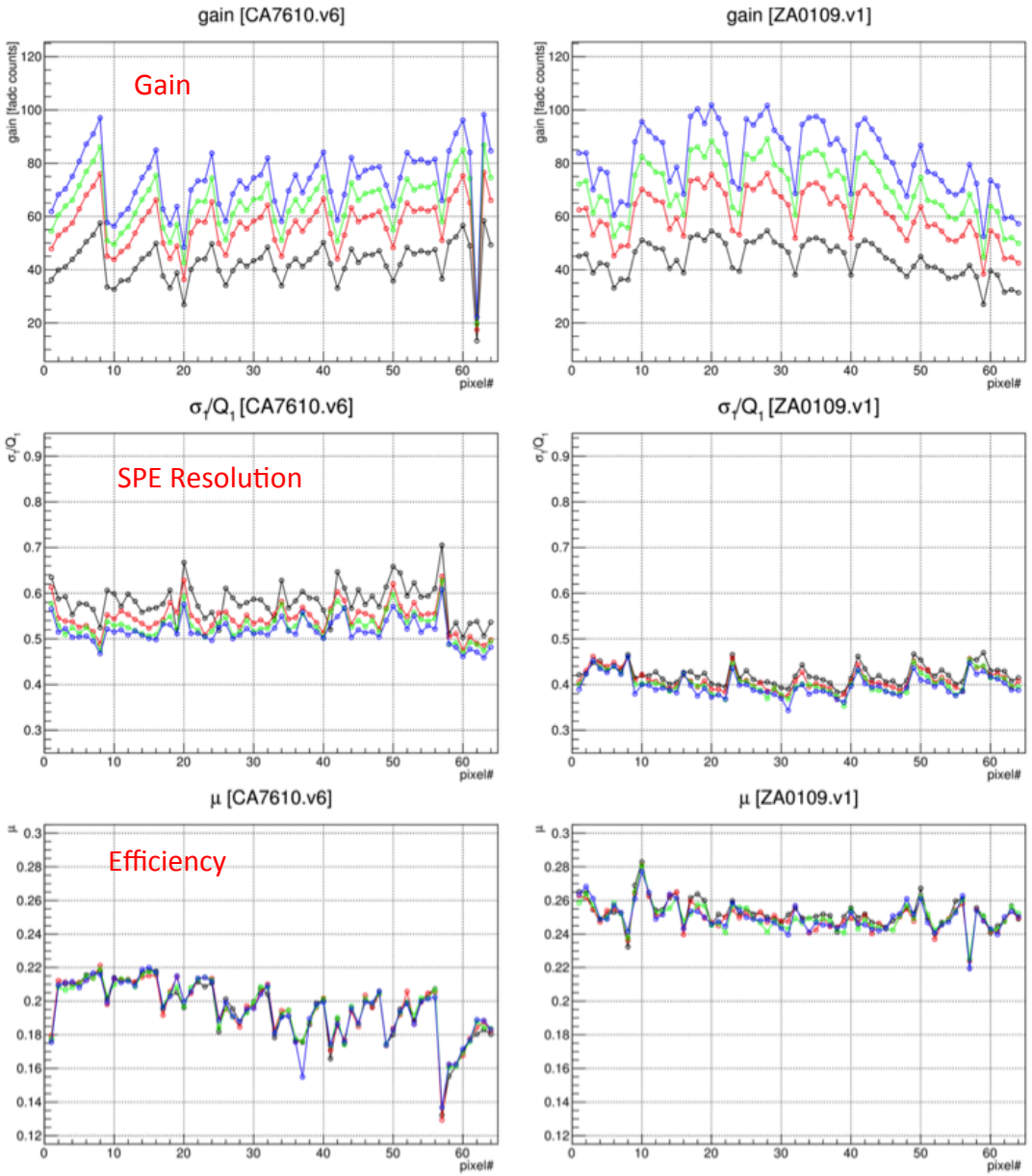


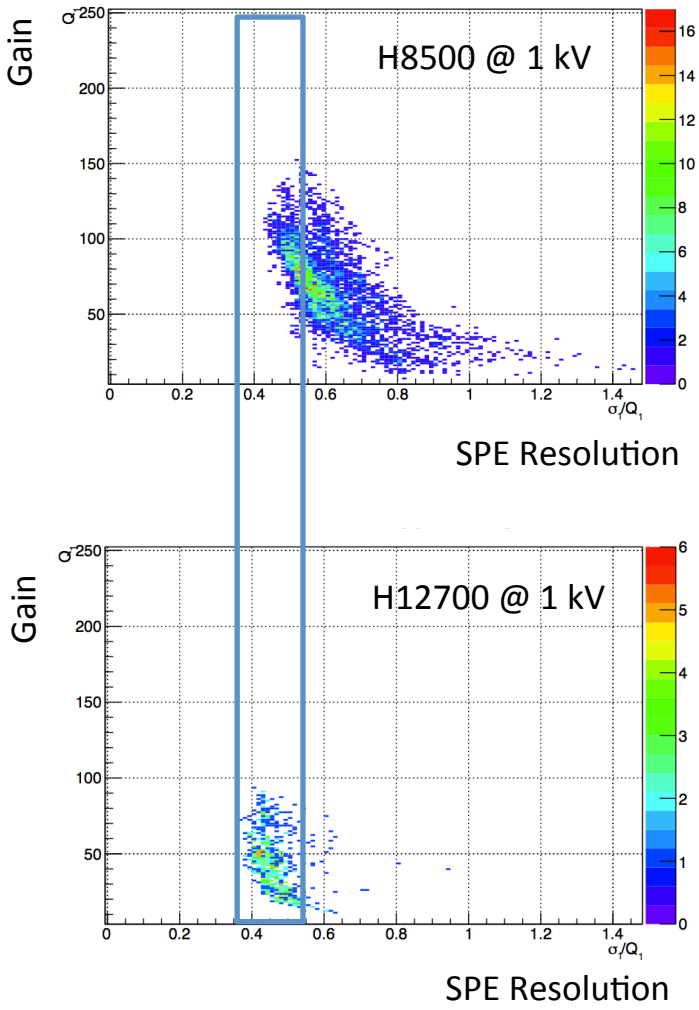
Reflected rings for less demanding low momentum particles



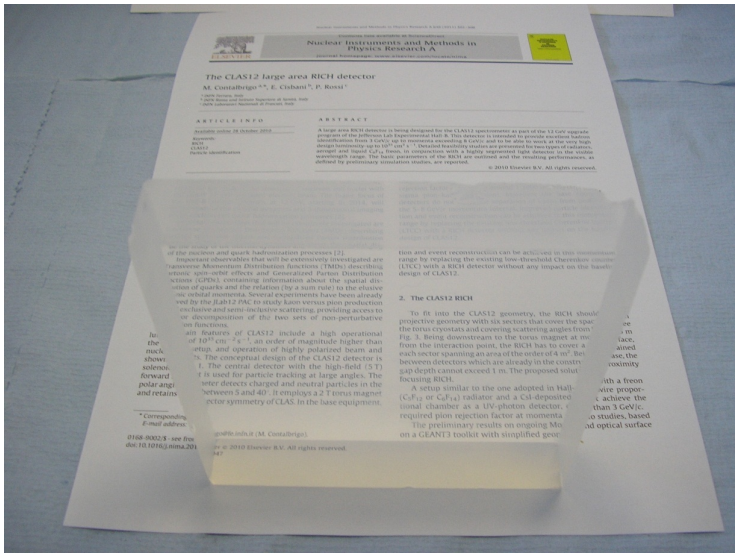
- Minimize active area (cost) to about 1 m^2
- Material budget concentrated where TOF is less effective
- Focalizing mirrors allow thick radiator for good light yield
- Time resolution < 1 ns to distinguish direct and reflected patterns

MA-PMT SPE Resolution





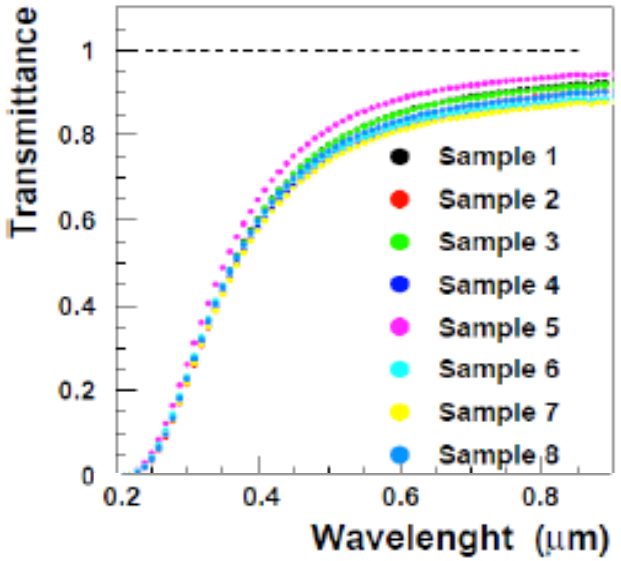
Aerogel Radiator

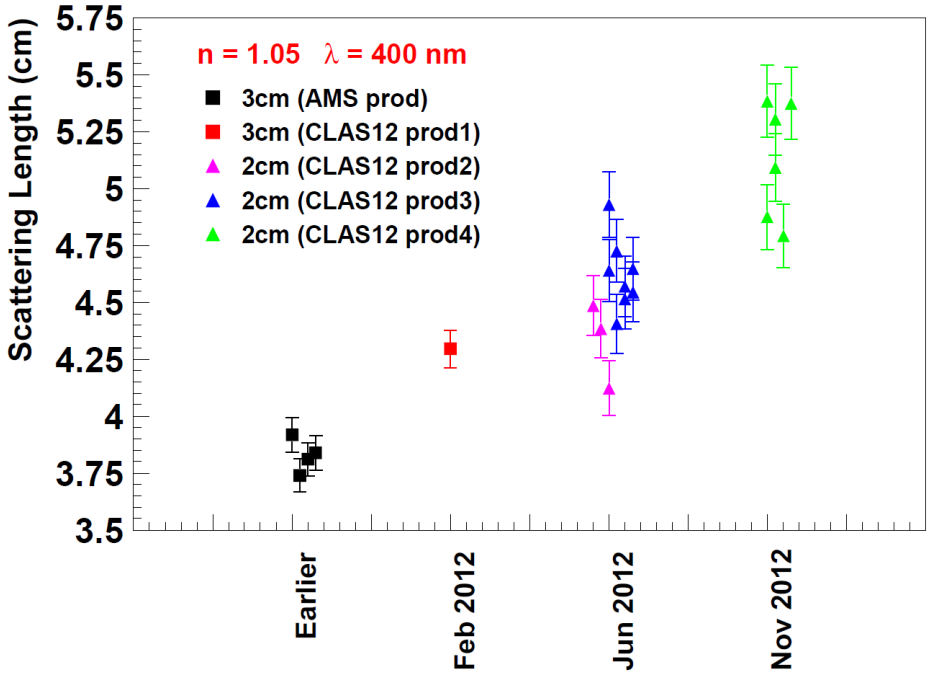


Achieved ~ 0.00050 $\mu m^4\ cm^{-1}$ clarity
for 115x11.5 cm^2 tiles at n=1.05*

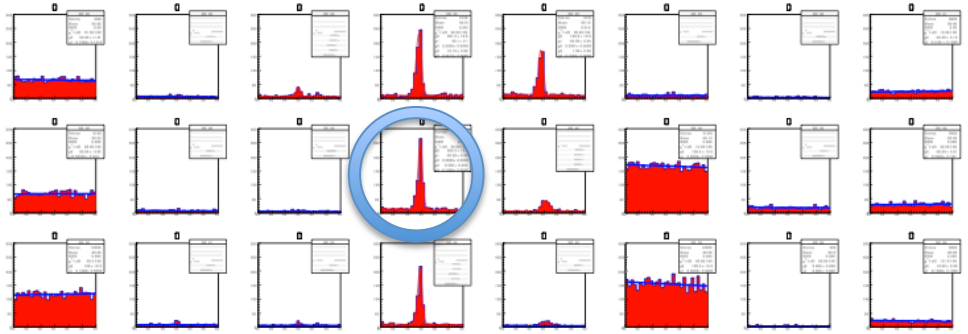
(comparable with LHCb at n=1.03)

*Budker and Boreskov Institutes of Novosibirsk

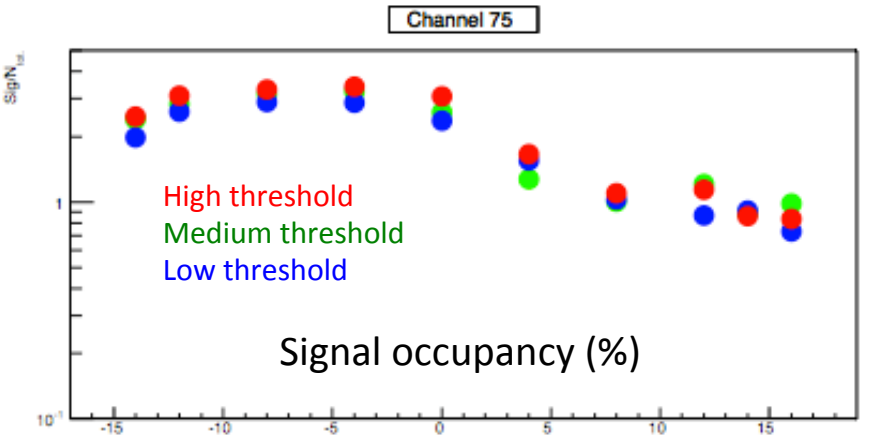




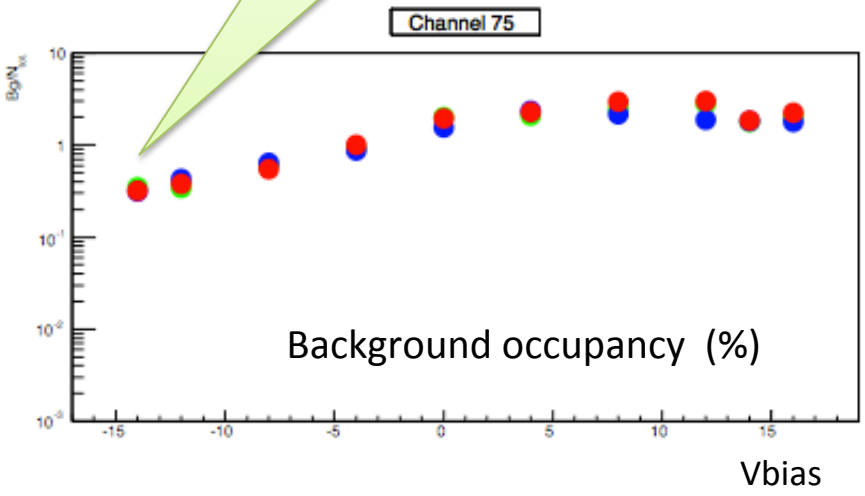
The Custom SiPM Matrix @ +25°

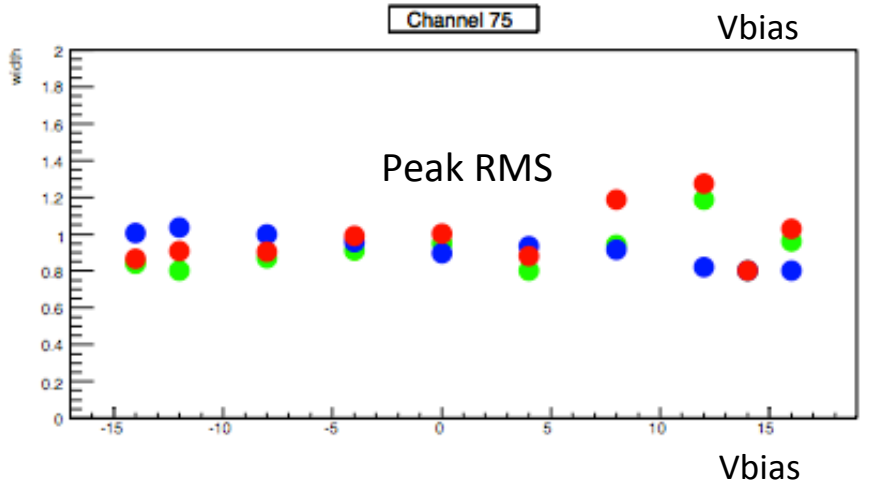


Equalization of the single SiPM is critical

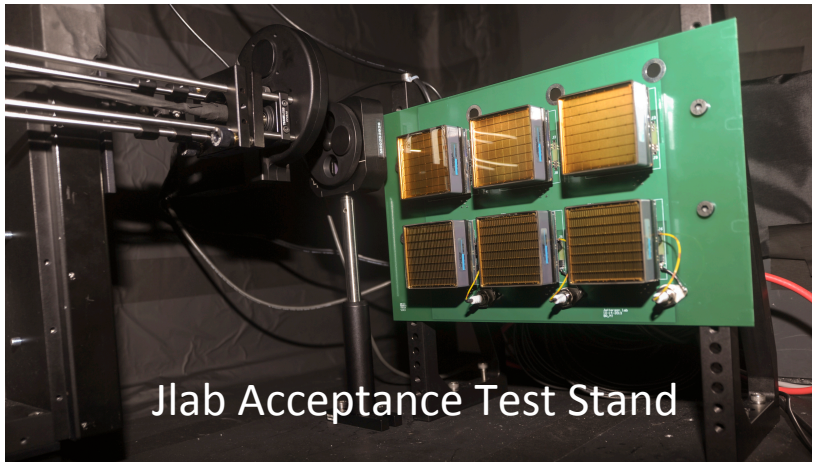


In a +/-3 ns window challenging 10^{-3} level

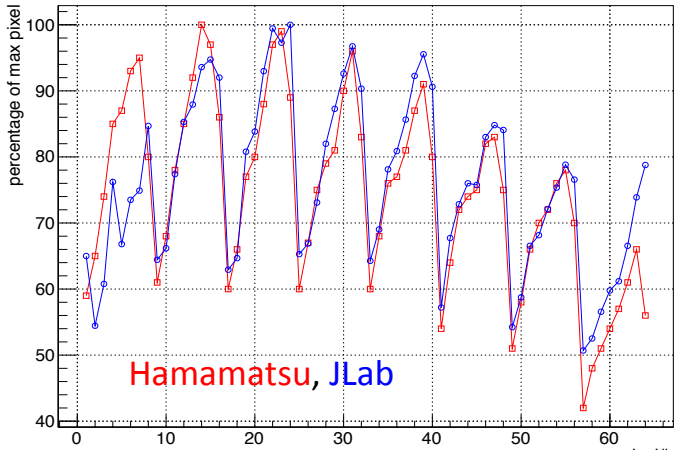




Novel H12700 MA-PMT



1:2 typical gain variation



Typical higher dark current for border pixels