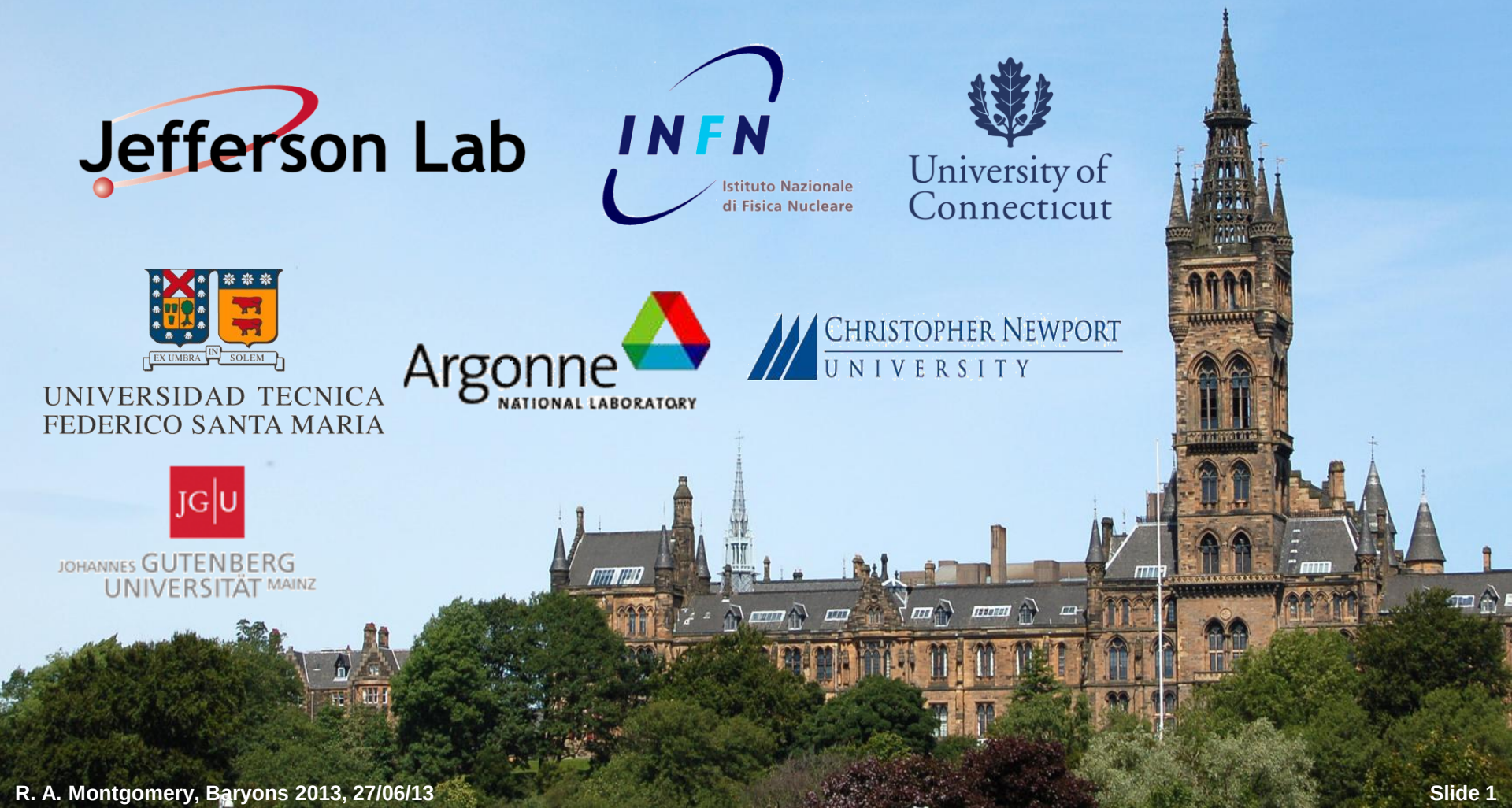
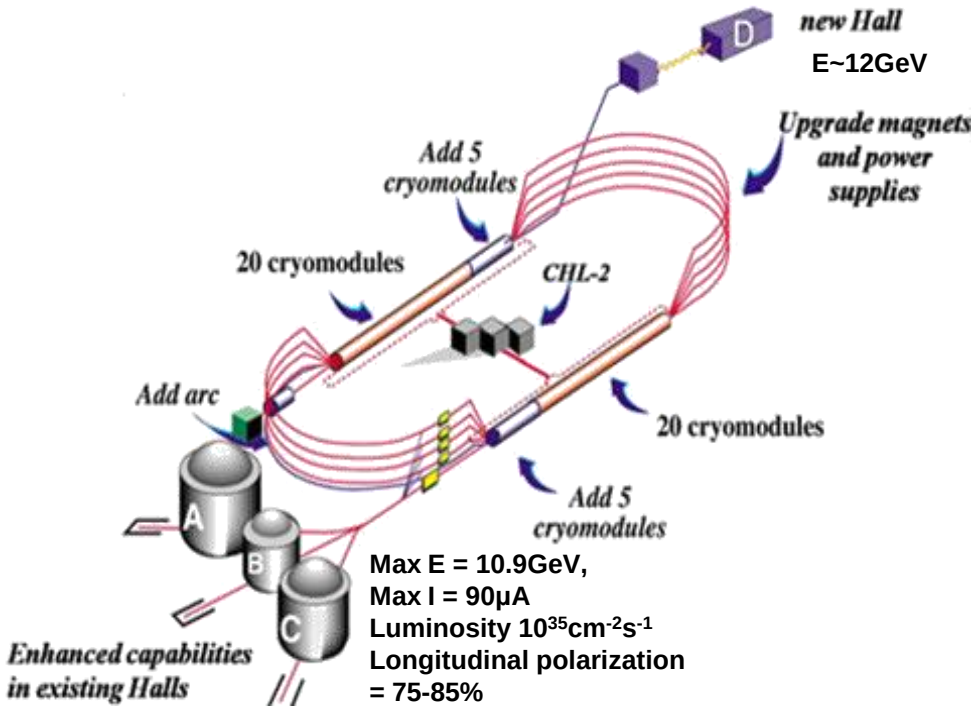
A Ring Imaging Cherenkov (RICH) Detector for CLAS12

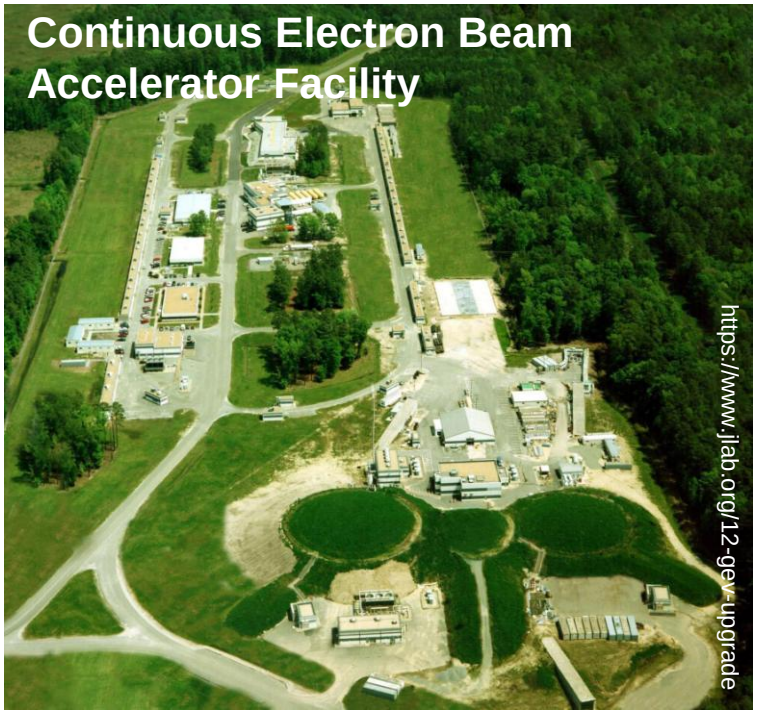
Rachel Montgomery, on behalf of the CLAS12 RICH Group:



CEBAF Upgrade at Jefferson Lab



Max E = 10.9GeV,
Max I = 90μA
Luminosity $10^{35}cm^{-2}s^{-1}$
Longitudinal polarization = 75-85%



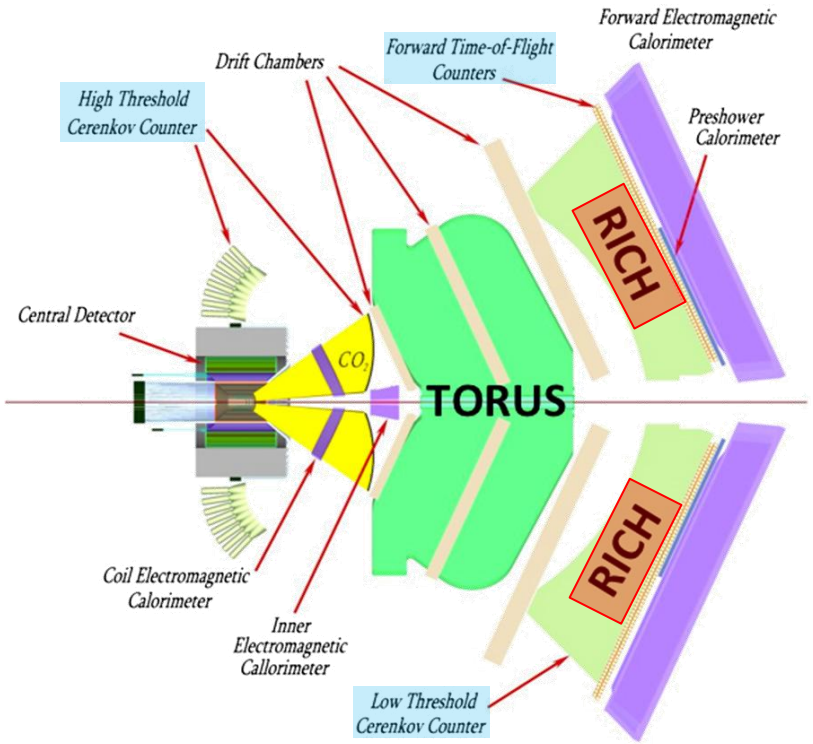
JLab 12GeV Upgrade:

- Shutdown 2012
- Electron beam **6GeV to 12GeV**
- Upgrade existing, install new detectors; new hall
- First beam delivery **Feb 2014**

CLAS12 and RICH Motivation

Hall B, CLAS ⟶ CLAS12:

Polarised/unpolarised lepton scattering experiments with close to full angular coverage



CLAS12 Physics Program:

- Internal nucleon dynamics, 3-D imaging of the nucleon; mapping of TMDs and GPDs
- Good separation of π, K, p over the full kinematics **3 – 8 GeV/c** necessary!
  - **π/K separation of ~4σ up to 8 GeV/c**
  - **RICH**

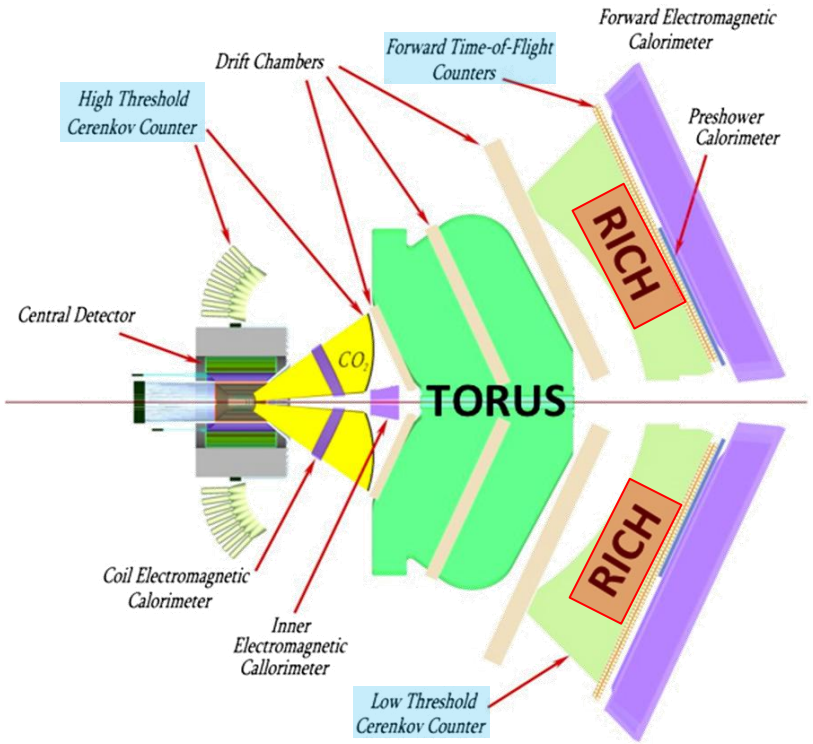
Physics Program	Particle Identification Requirement
Internal nucleon dynamics	Flavour tagging
Quark hadronisation in nuclear medium	Constraining models
Spectroscopy	Rare processes

Rossi, P. (2011), CLAS12 2nd European Workshop, Paris, March 2011

CLAS12 and RICH Motivation

Hall B, CLAS ⟶ CLAS12:

Polarised/unpolarised lepton scattering experiments with close to full angular coverage



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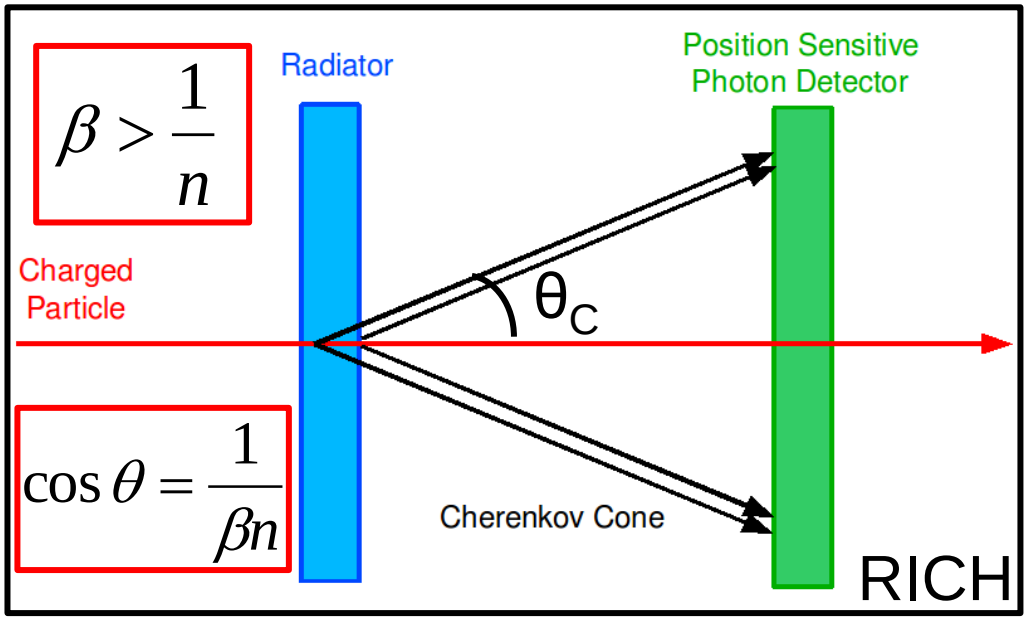
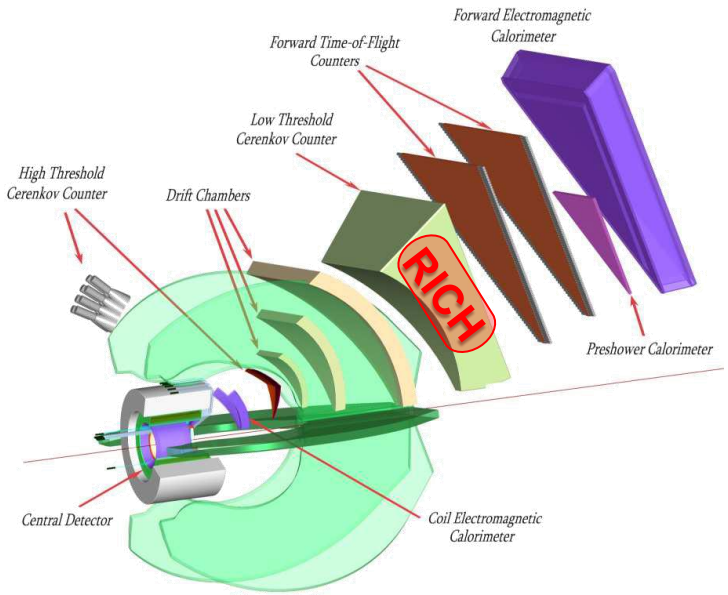
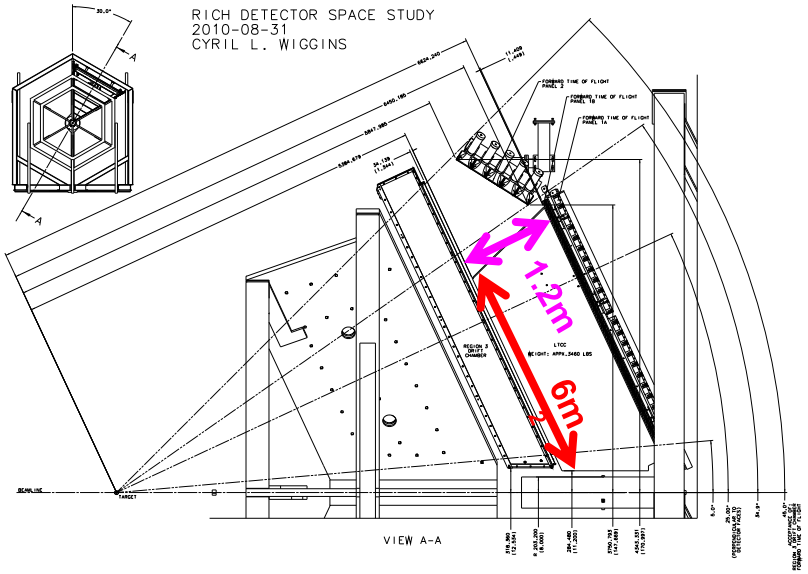
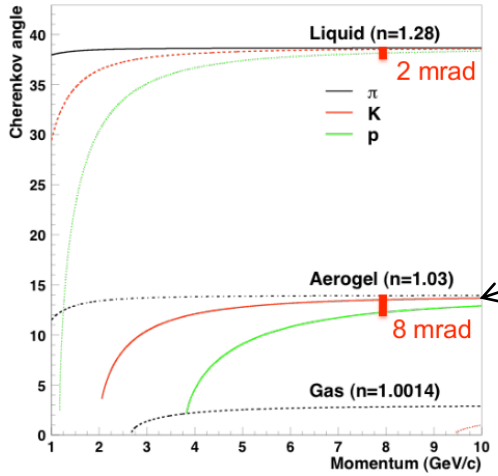


CLAS12 RICH Design: Available Space, Components Choice

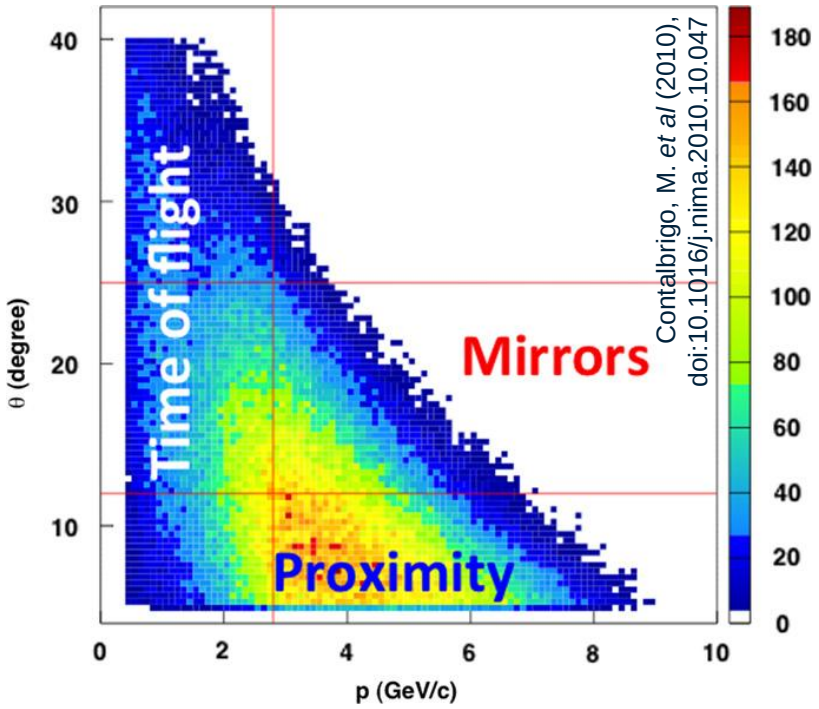






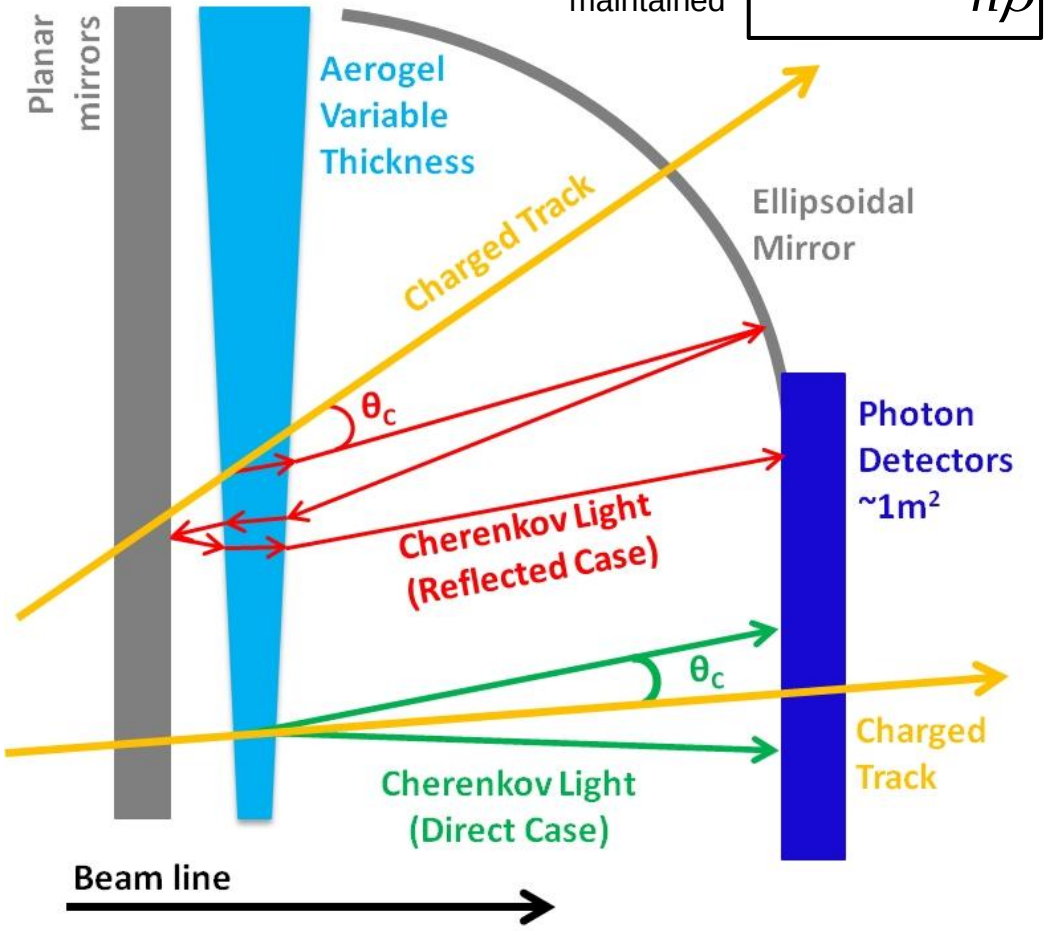
- **6 Radial Sectors:** 1.2m gap; ~6m^2 window
- **Hybrid Imaging RICH:**
  - **Aerogel** radiator (SiO_2+Air, n=1.01 - 1.13, δ = 0.05 – 0.6 g/cm^3)
  - **Visible light** photon detectors
  - **Focussing** mirror system → **minimise area**

CLAS12 RICH Design: Hybrid Imaging



Cherenkov angle maintained

$$\cos\theta_C = \frac{1}{n\beta}$$



Direct Case (proximity):

- θ<12º, p = 3 – 8GeV/c

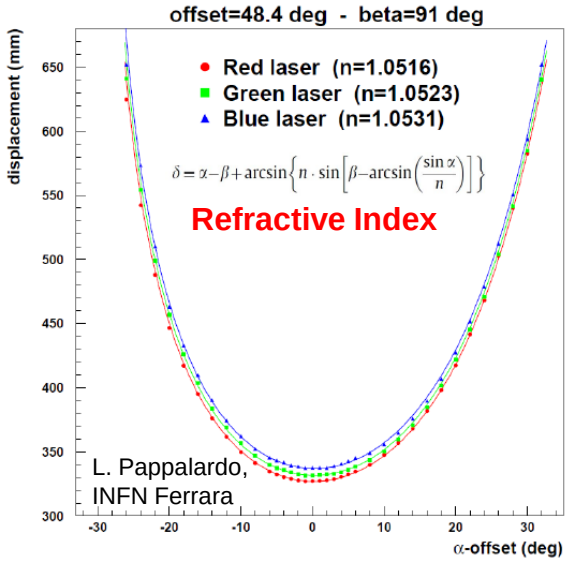
Reflected Case:

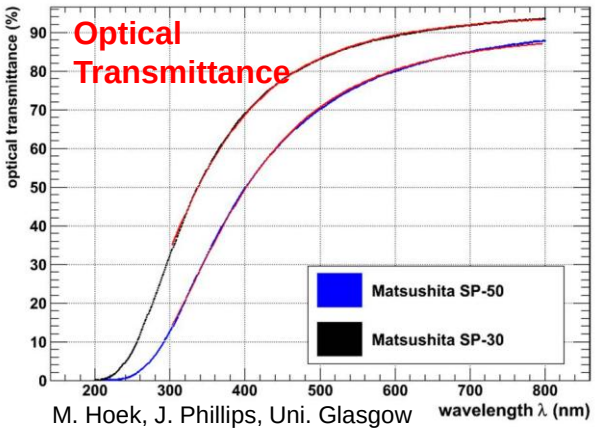
- θ>12º, p = 3 – 6GeV/c

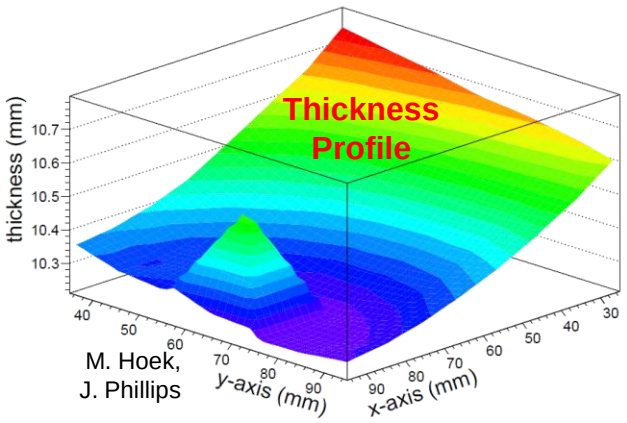
Aerogel as a Radiator Material

Radiator Material: Aerogel (n=1.04 to 1.06)

- Momentum range (3 – 8 GeV/c)
- Constrained depth, low-material budget (3.2% X_0)
- **Characterise optical properties:** reflected case and simulation input
- **Refractive index** (prism method), **transmittance** (spectrophotometer), **thickness profile** (coordinate machine)
- Different manufacturers: Novosibirsk, Matsushita, Aspen







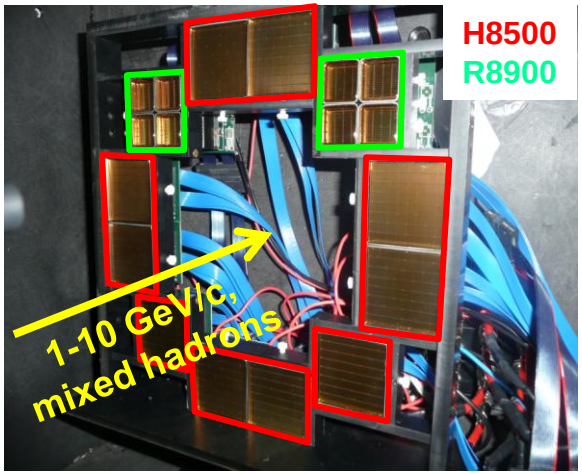
Photon Detectors – Requirements, Hamamatsu H8500

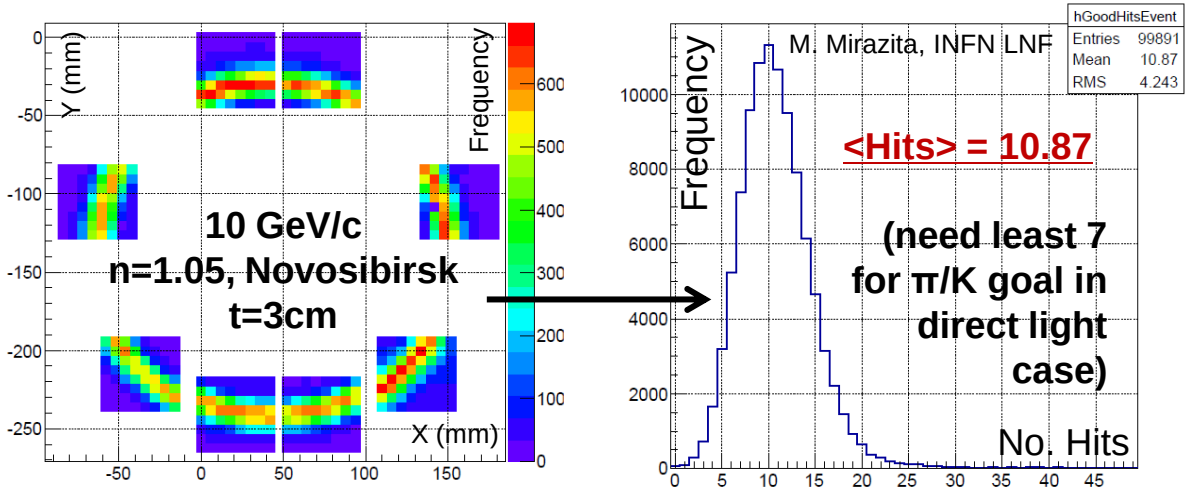
MAPMT Parameter	H8500
Active Area (mm x mm)	49 x 49
Number of Pixels	64 (8 x 8)
Pixel Size (mm x mm)	5.8 x 5.8
Packing Fraction (%)	89
Range (nm)	260 - 650

Requirements:

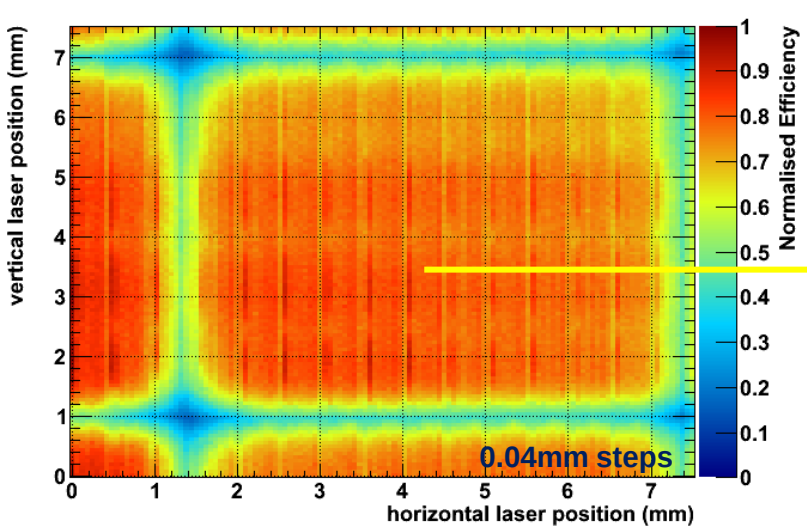
- Position sensitive
- Pixel sizes < 1cm x 1cm
- Efficient single photon detection crucial
- High packing fraction
- Sensitivity to visible light

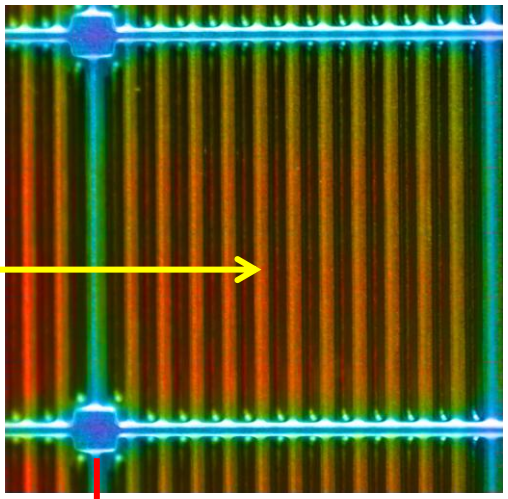
✓ **Hamamatsu H8500 MAPMT**

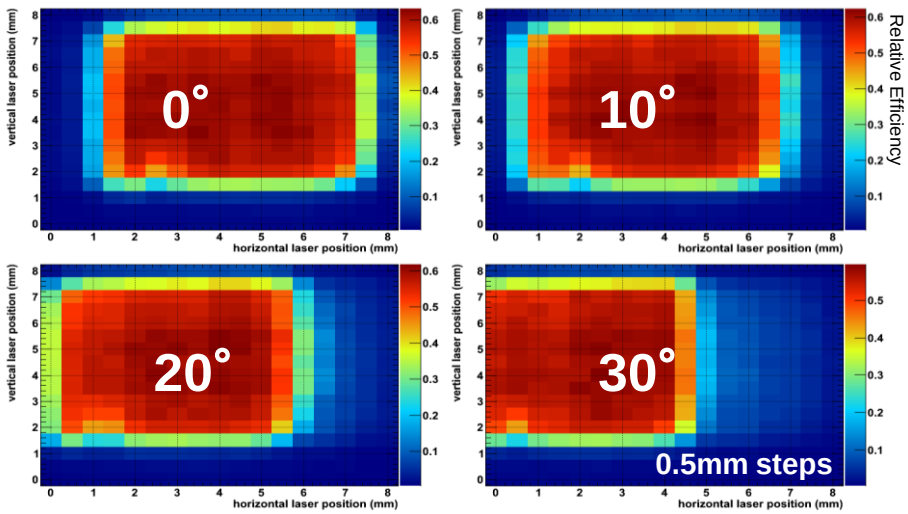


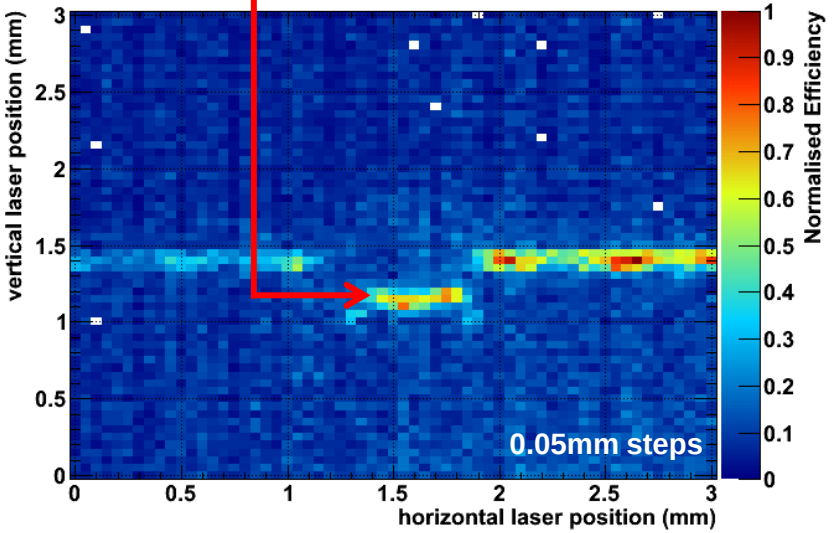


Photon Detectors – Single Photoelectron Scans







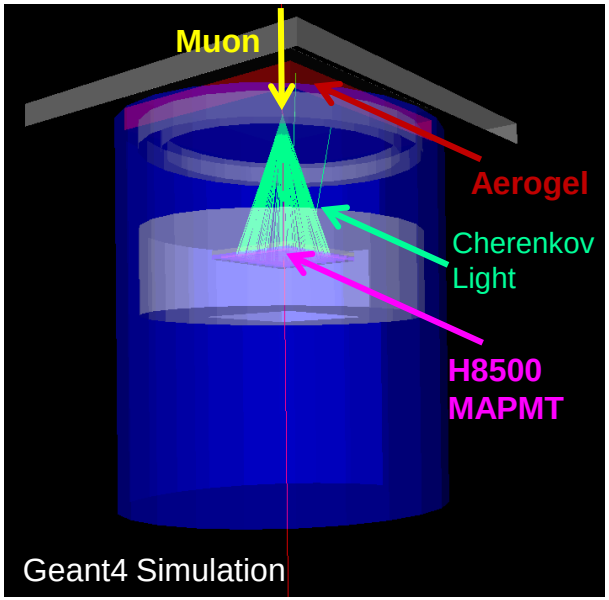


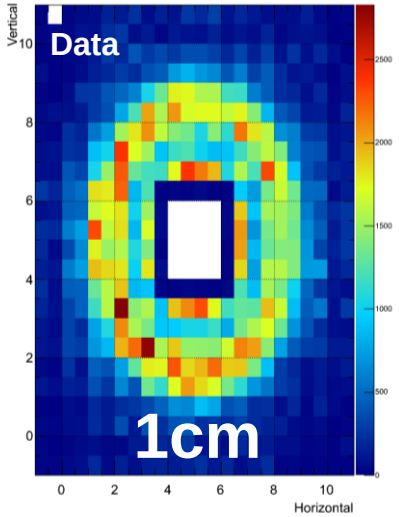
Cosmic Prototype for MAPMT Simulation Model Validations

Background Corrected Yields:

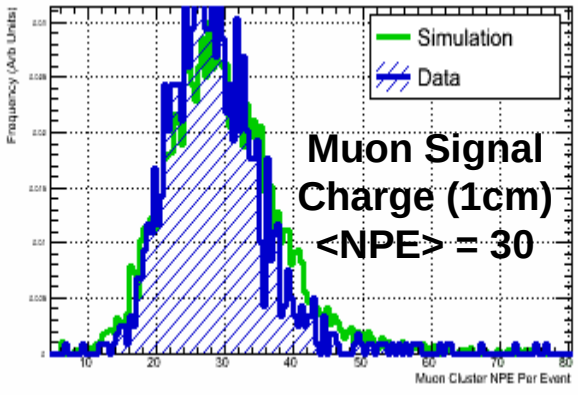
Data Set	Algorithm	Aerogel Yield (NPE)
1cm	Cluster	9.22±0.29
1cm	Template	10.26±0.26
2cm	Cluster	12.87±0.24
2cm	Template	13.99±0.24

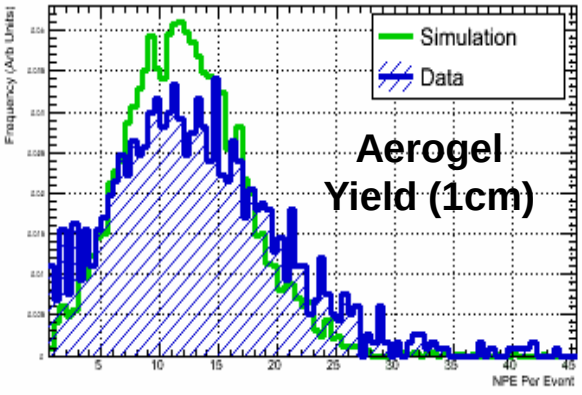
n.b. 10% uncertainty from gain calibration

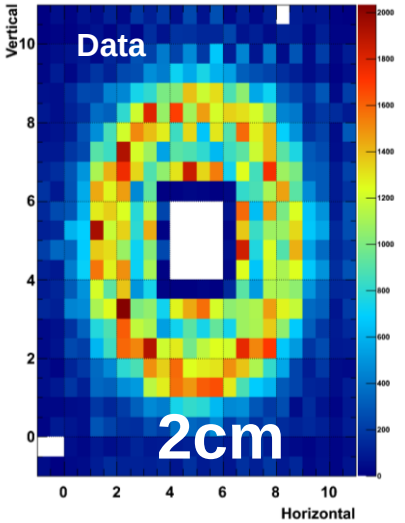




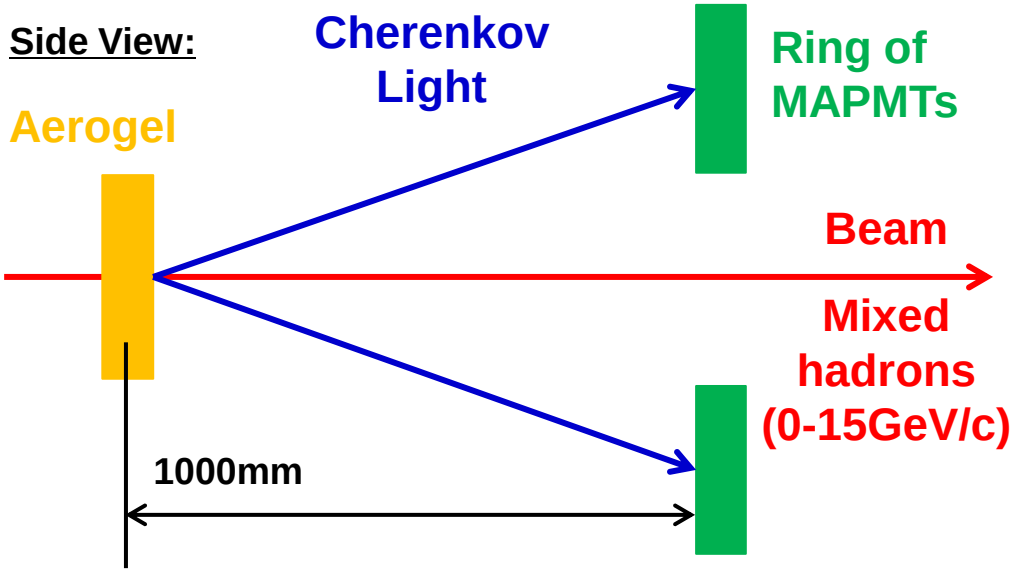
Data Vs Simulation:







Testbeam Prototype Setup – Direct Light Configuration



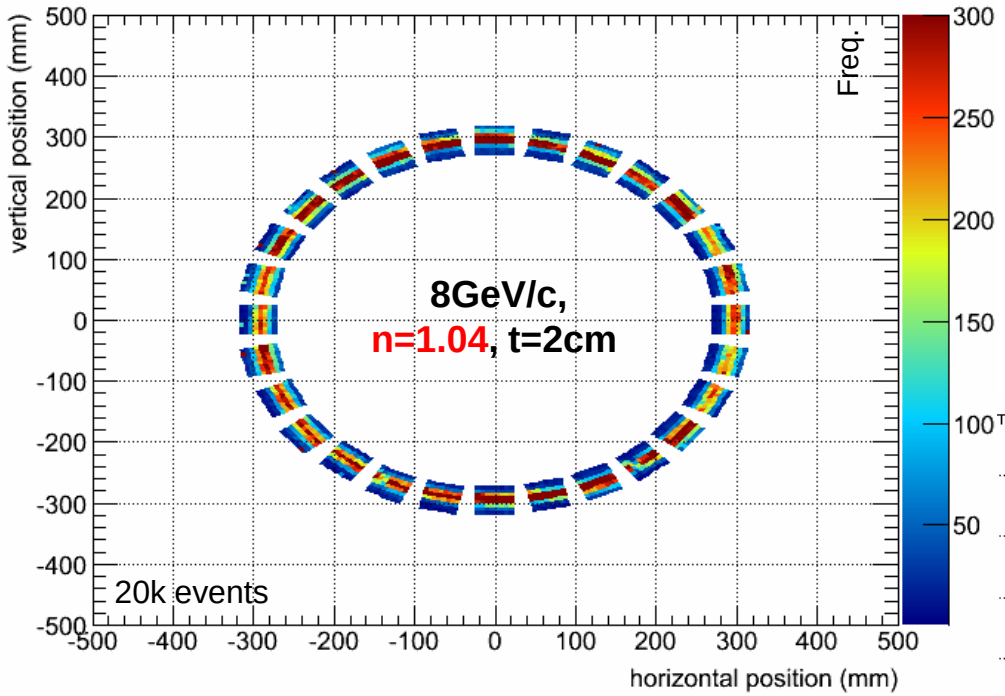
MAPMTs:

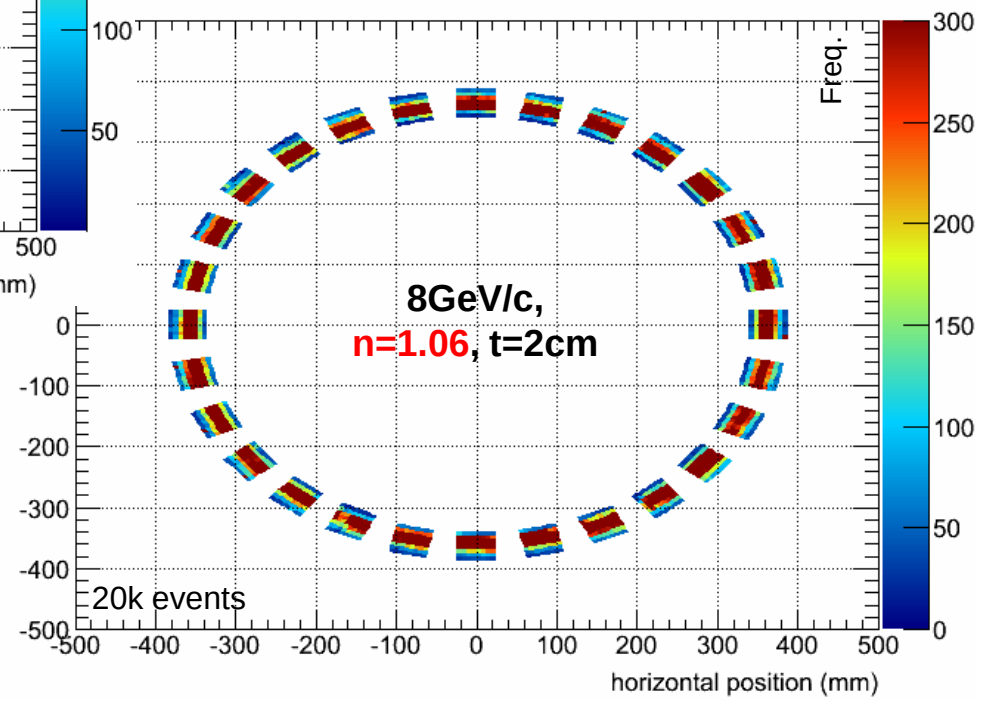
- 28 **H8500** MAPMTs (14 normal, 14 UV-extended windows)
- Readout **MAROC3** electronics (ADC)

Aerogel (Novosibirsk):

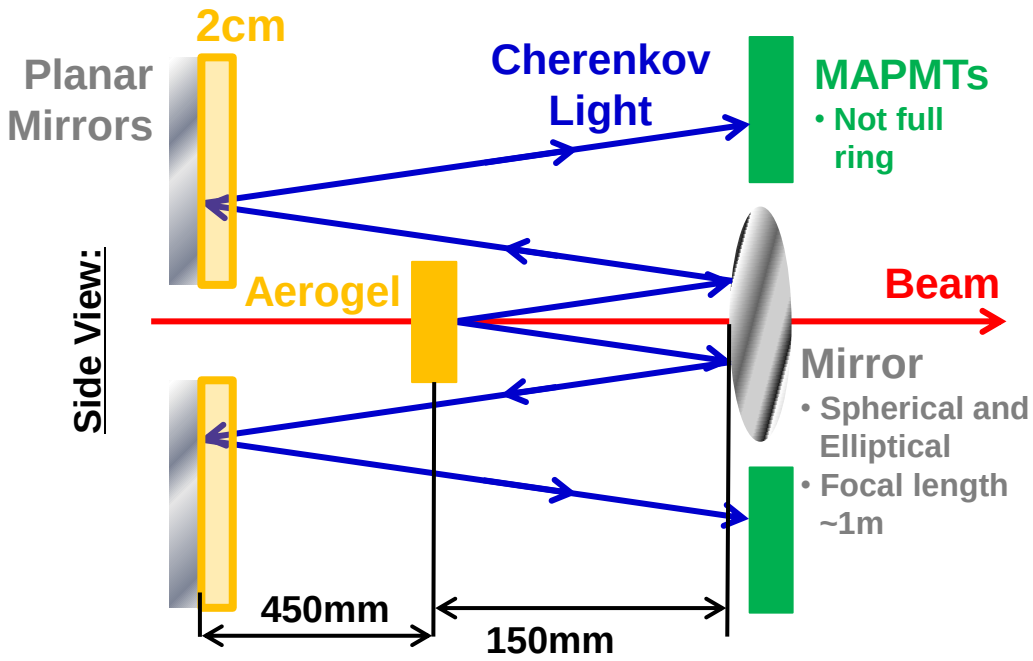
- Varying n, thickness, transparencies
- Transparency monitored – laser and photodiode

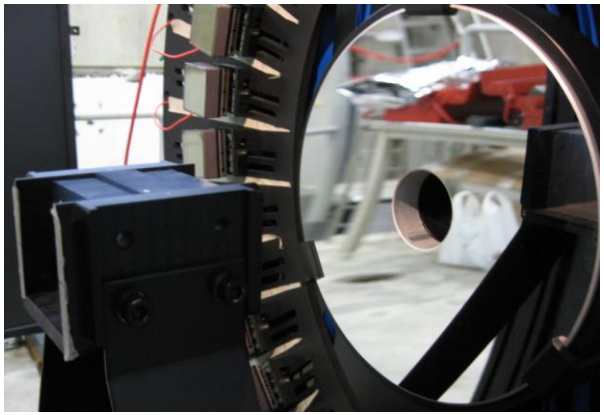
Testbeam Prototype Images – Direct Light Configuration





Testbeam Prototype Setup – Reflected Light Configuration

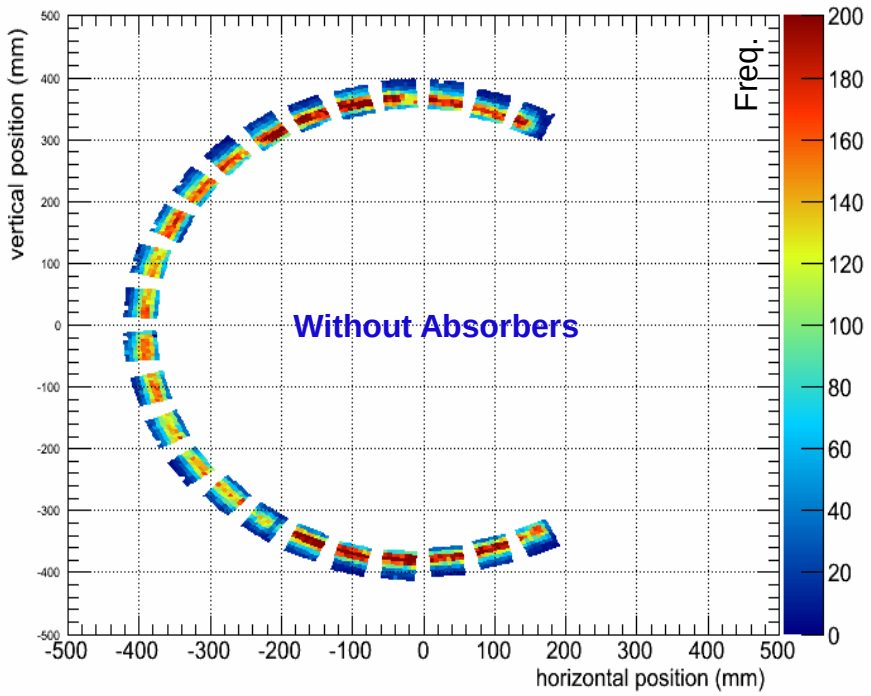


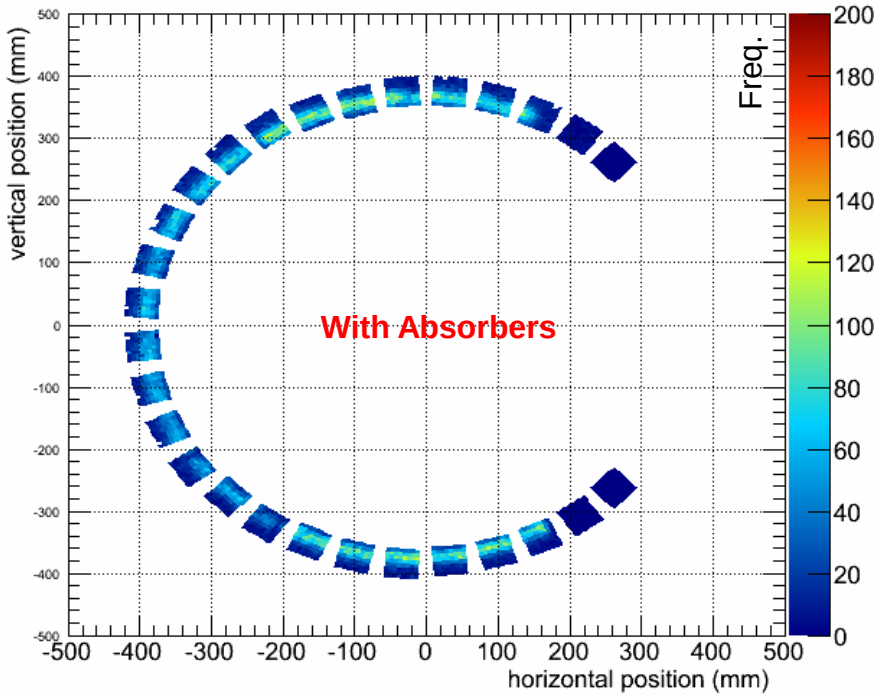


- **Absorbers**: Novosibirsk, CERN AMS samples
- n=1.05, t=2cm, **varying transparency**

Testbeam Prototype Images – Reflected Light Configuration

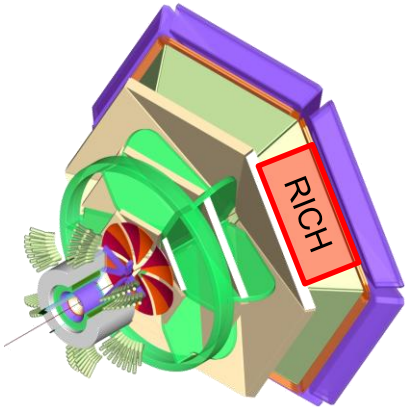
Radiator n=1.05, t=6cm; Beam p = 6GeV/c: Comparison with and without absorbers:



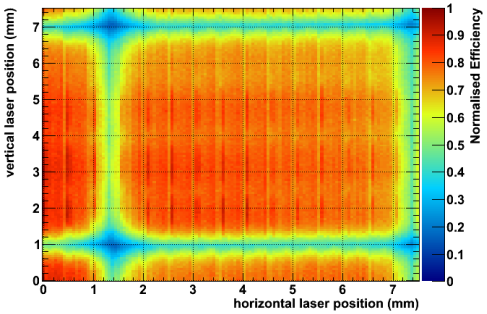


Summary and Outlook

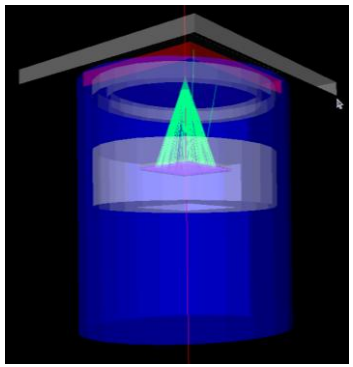
CLAS12:



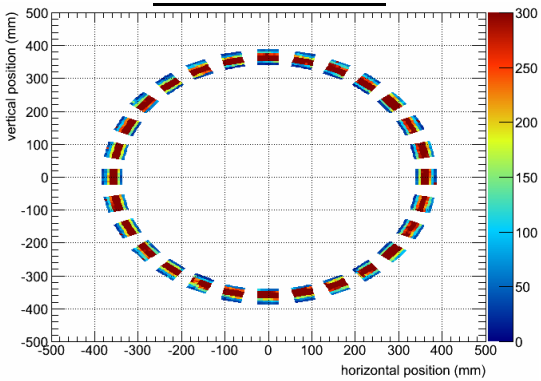
Components Testing:



Cosmic Stand:



Testbeams:

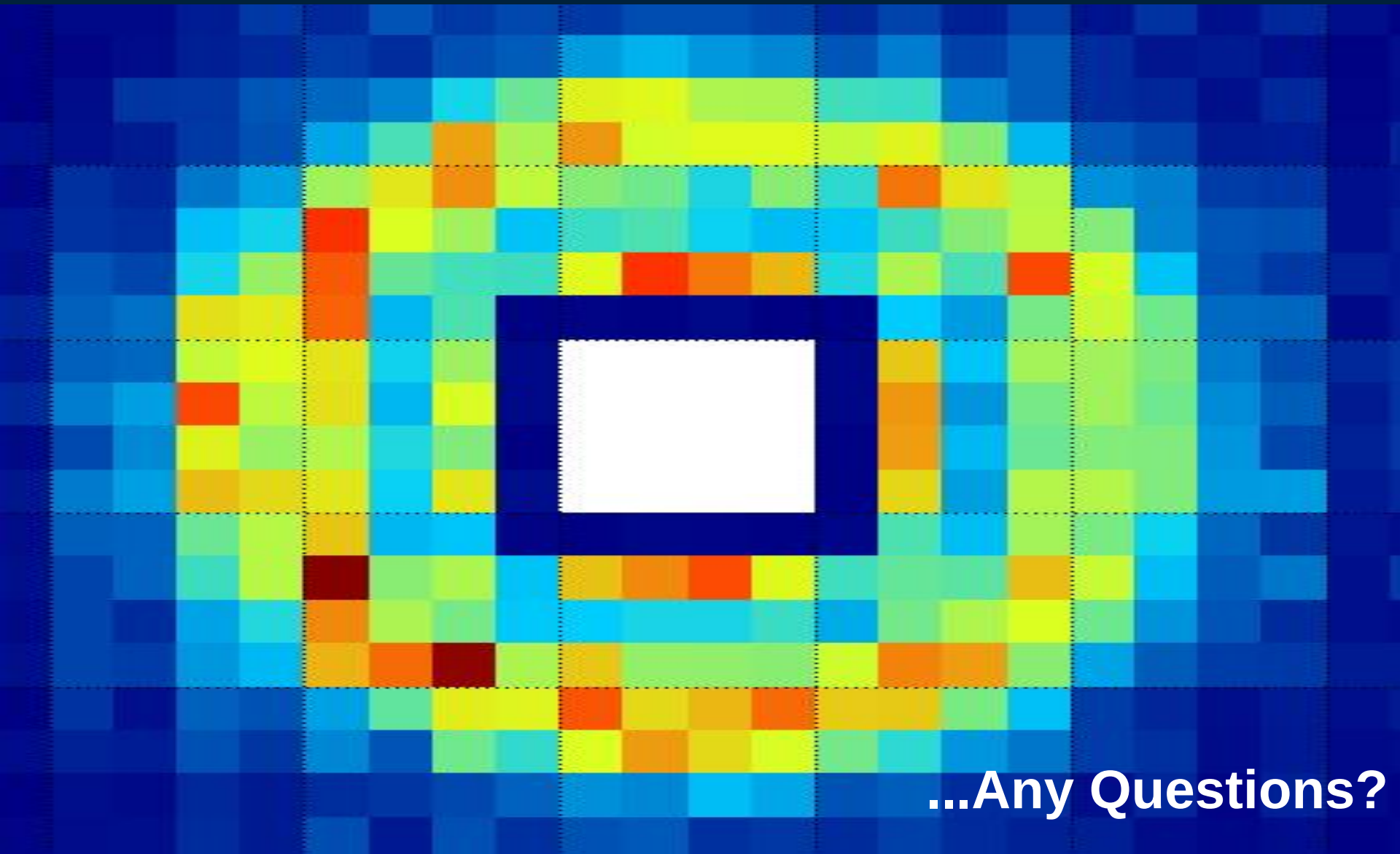


Outlook:

- Technical design report currently underway
- Completion and installation of one complete RICH sector planned for beginning of CLAS12 data taking

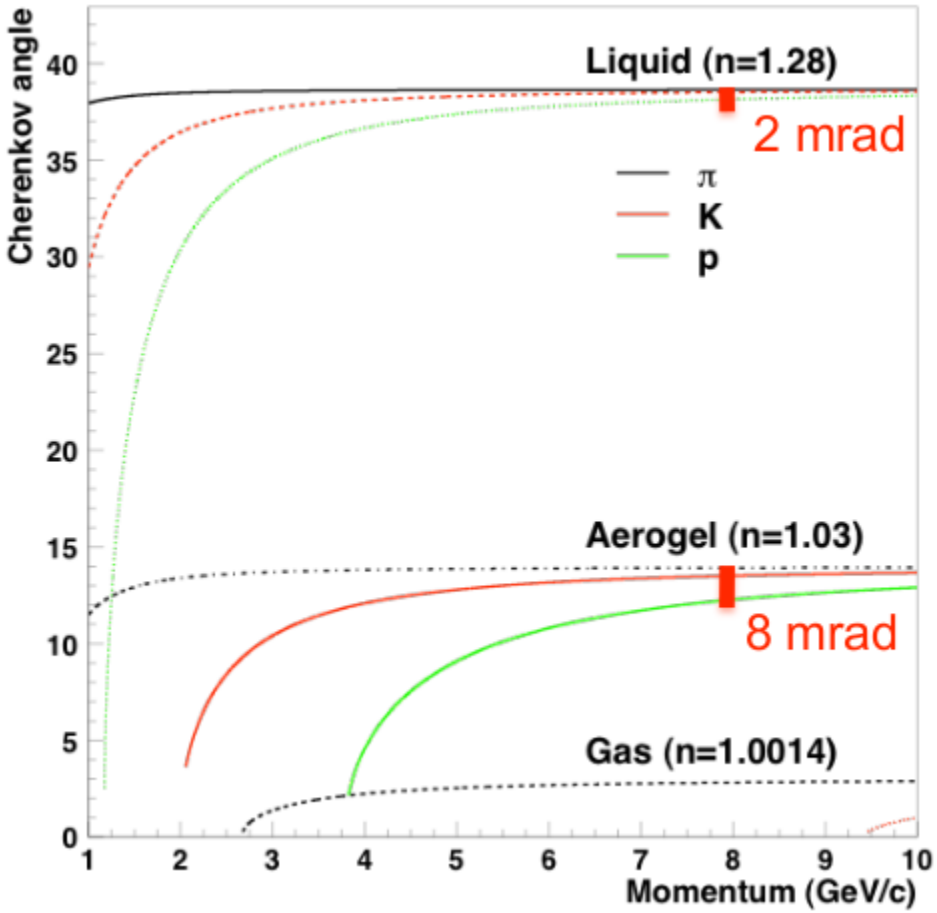
University of Glasgow

Thanks for your Attention

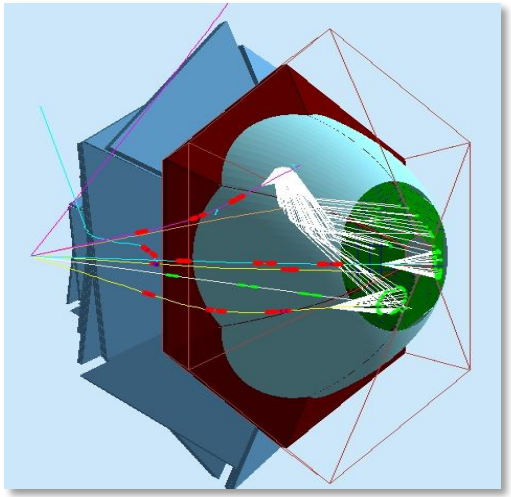


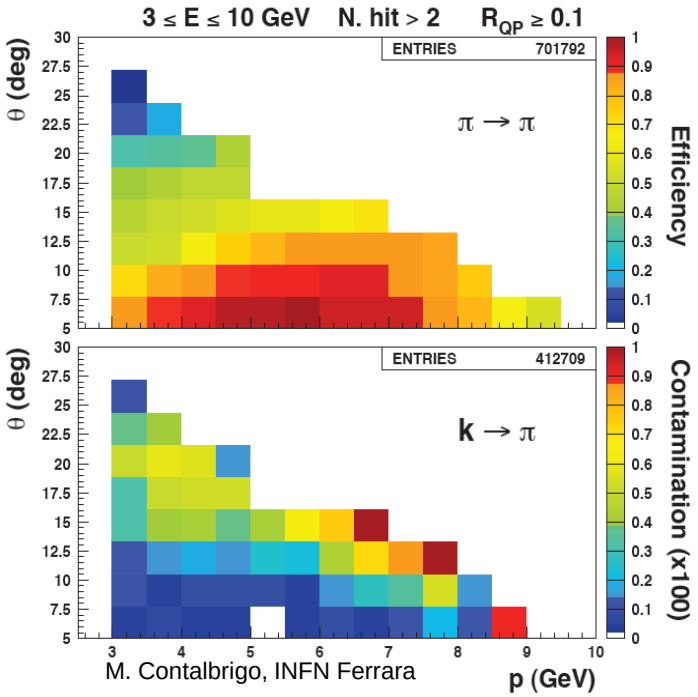
...Any Questions?

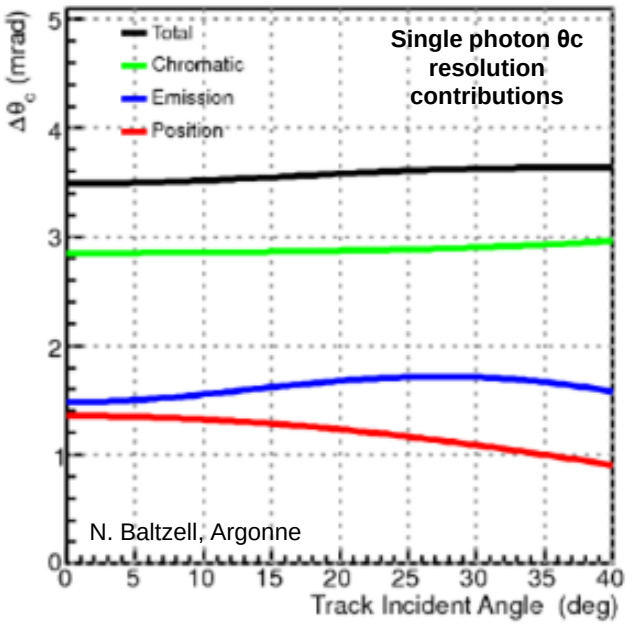
Radiator Selection



Simulation, Reconstruction, Expected Performance







Simulation Studies:

- **Geant4** framework
- **Pattern reconstruction**: Maximum Likelihood, ray tracing ansatz

Requirements:

- **Direct** case, aim: 8GeV/c π/K separation 5.5mrad
  - ➢ require **7** detected photoelectrons
- **Reflected** case, at least **3** detected pe's for algorithm

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Pixel Size (mm x mm)	5.8 x 5.8
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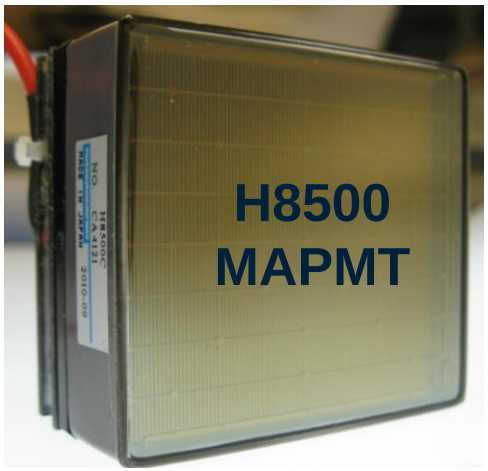
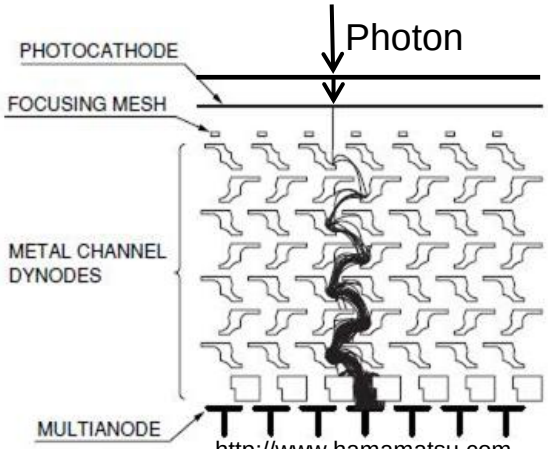
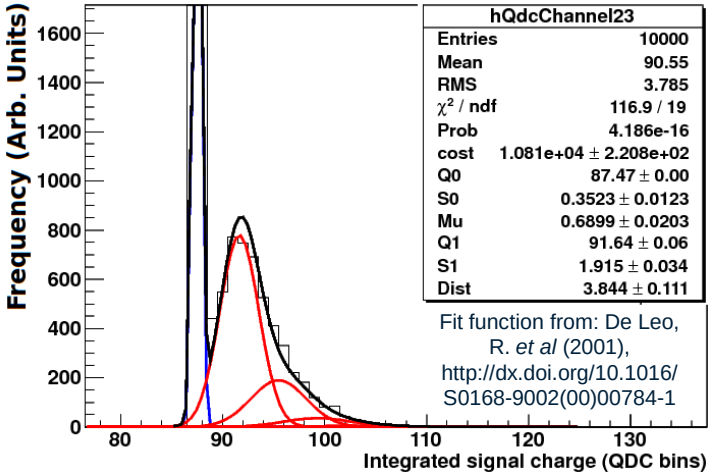
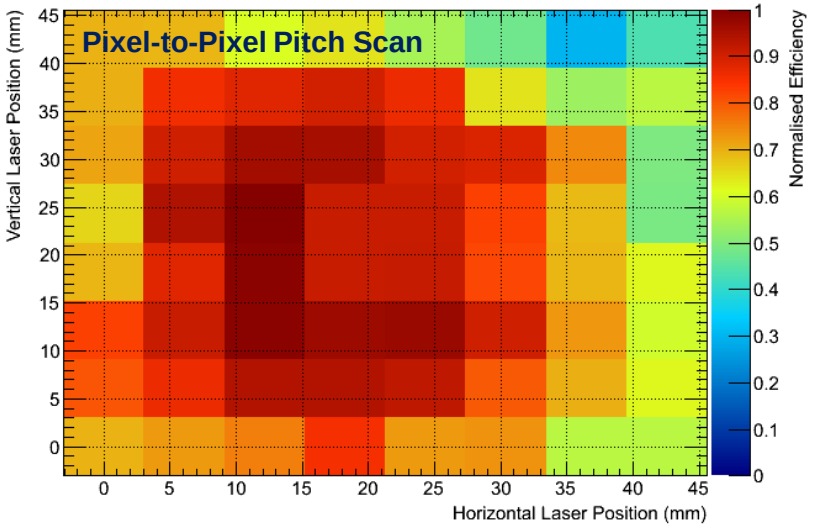




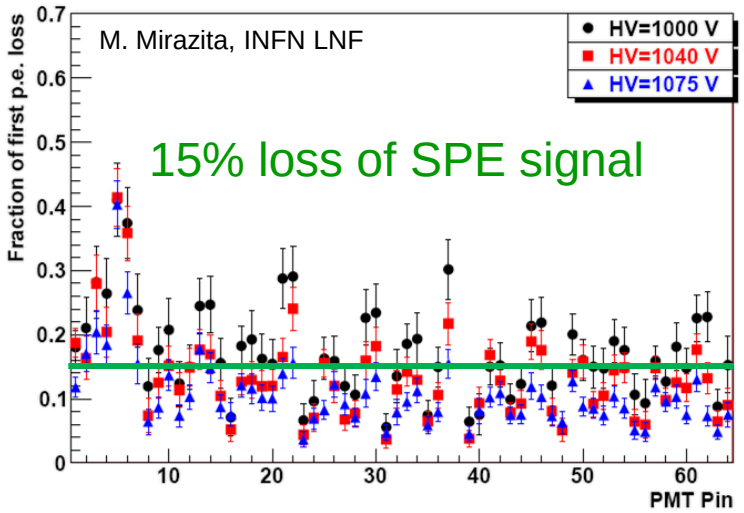


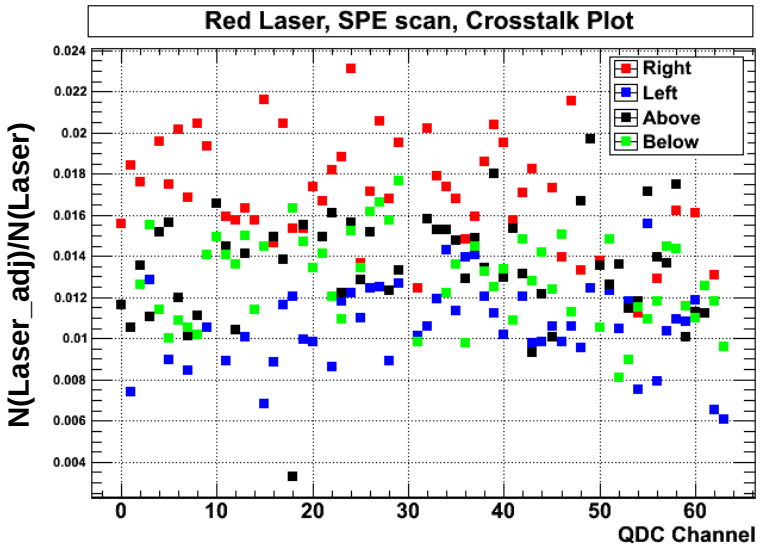
Photon Detectors – Single Photoelectron Responses



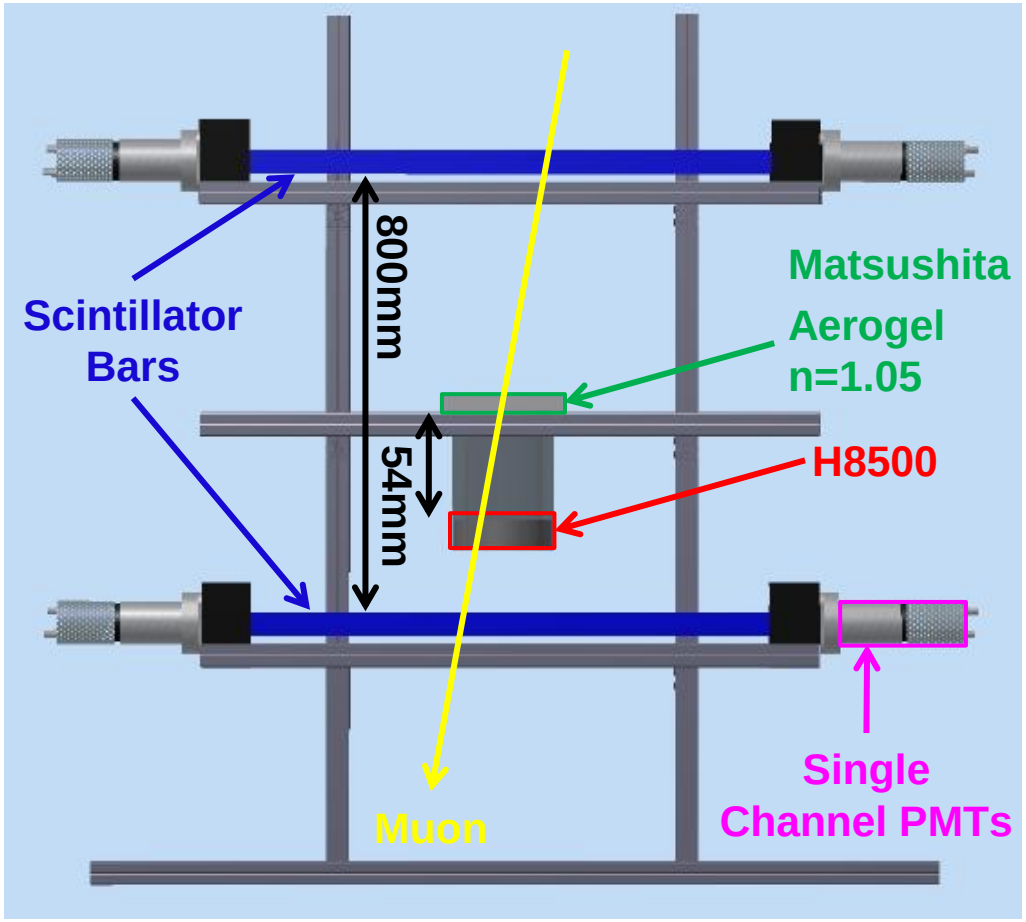
Detector Characterisations:

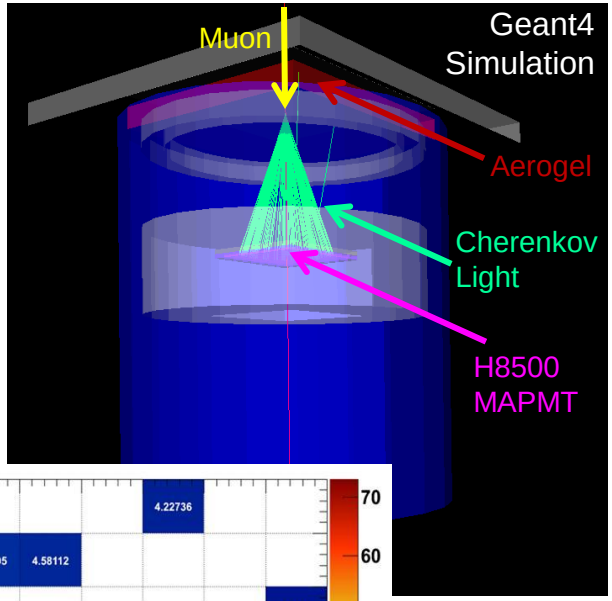
- Uniformity studies
- Single photon signal losses
- Crosstalk studies
- H9500, H7546 amongst tested

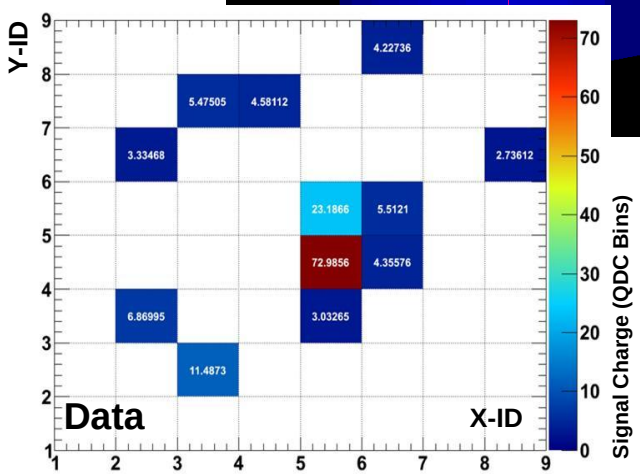




Cosmic Prototype for MAPMT Simulation Model Validations







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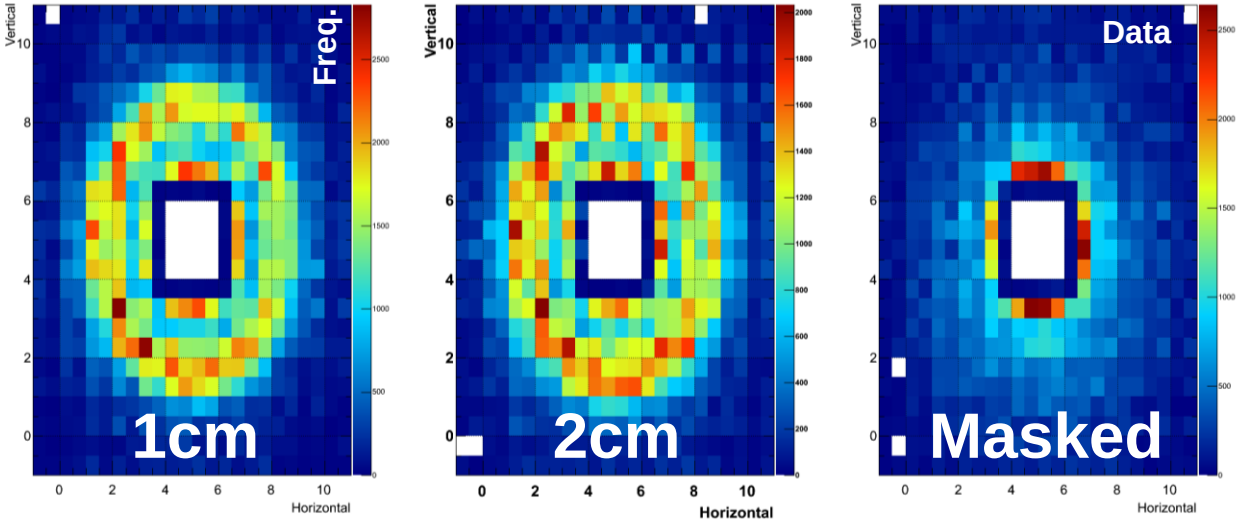
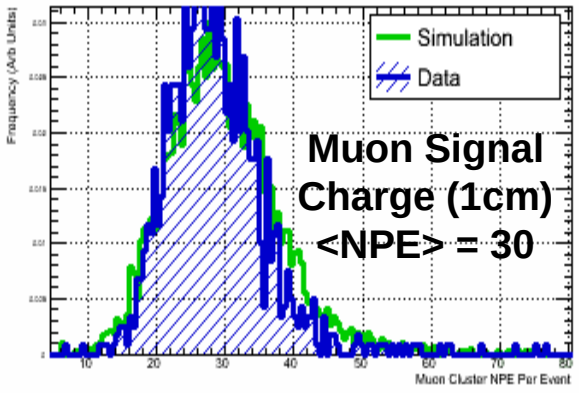
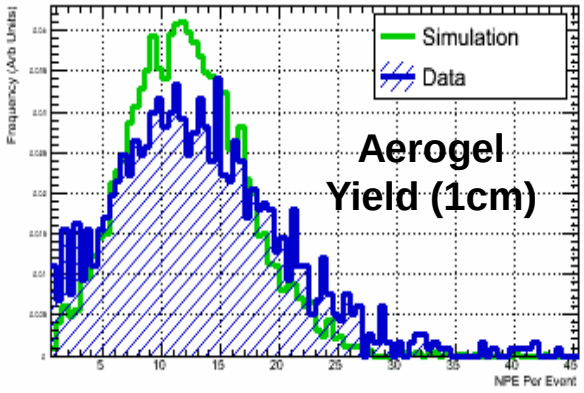
2cm	Template	13.99±0.24

n.b. 10% uncertainty from gain calibration



Data Vs Sim:

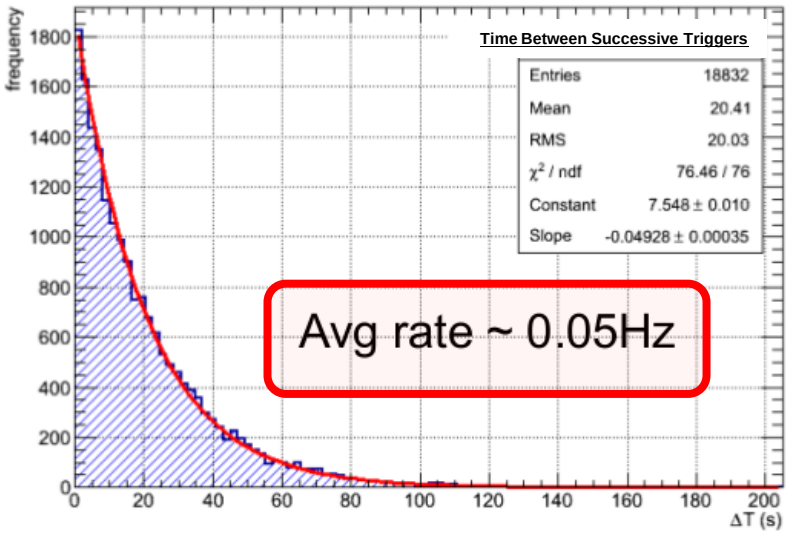




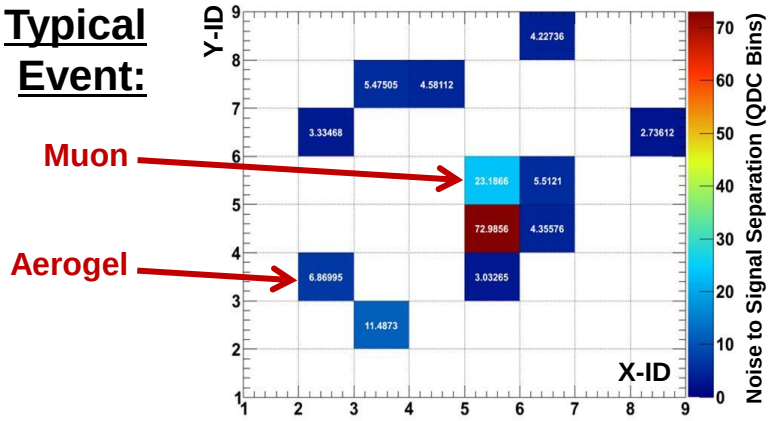
- Muon hit in MAPMT window well-modelled
- Aerogel yield requires pixel single photon resolution variations

Cosmic Prototype: Trigger Rate, Data Sets and Event Topology

Trigger Rate:



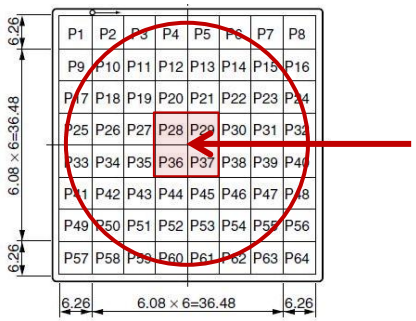
Typical Event:



Data Sets:

- **1cm** aerogel
- **2cm** aerogel (2 x 1cm tiles)
- **Masked** data – MAPMT window covered

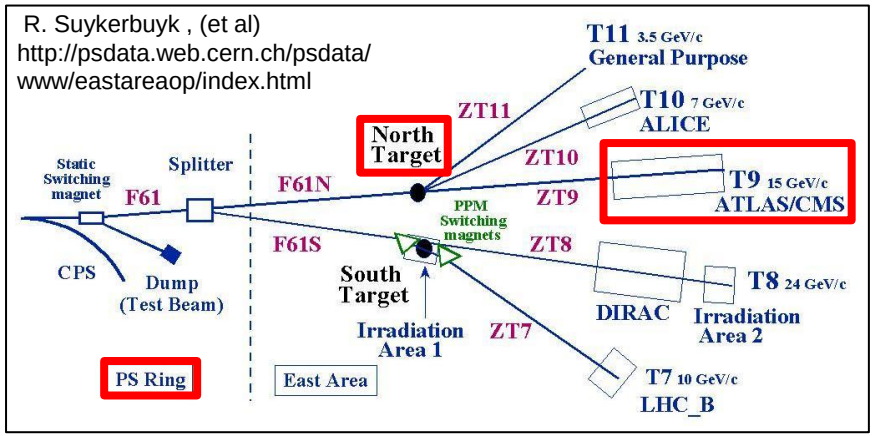
Data Set	No. Events	No. Central Hits	Eff. (%)
1cm	135 832	1 205	0.89
2cm	198 000	1 797	0.91
Masked	189 000	1 749	0.93

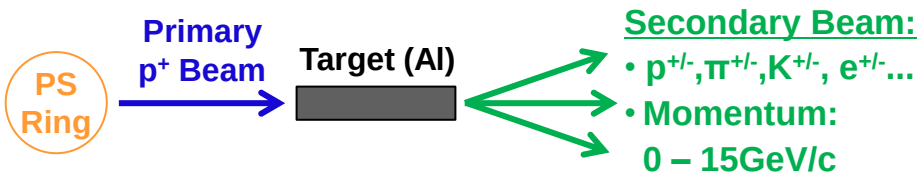


Only **central muon hits** are used, to maximise ring coverage:
<Eff> = 0.91 ± 0.01

Prototype Studies at Testbeams

- **CERN PS East Area, T9 beam test area** (Jul-Aug 2012 and Nov-Dec 2012):



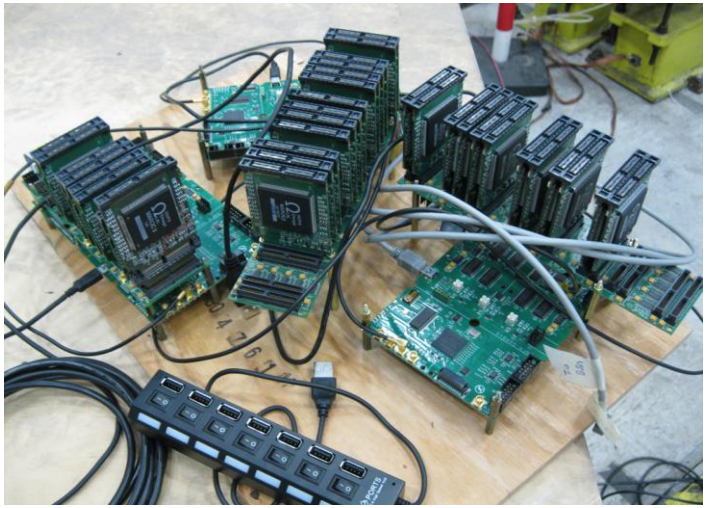


Testbeams:

- Negative polarity; momenta 6,7,8 GeV/c
- At 8 GeV/c, π:K ~ 60:1

Prototype Detector Setup: FE Electronics

Prototype:
1952 Channels;
33 FE Cards;
3 Backplanes;
3 Control Boards



Readout – MAROC3:

- 64 channel charge ADC readout
- x4 Pre-amp – equalise gains
- digital outputs available