dRICH development - design and performance

E. Cisbani + (next slide)

Italian National Institute of Nuclear Physics – Rome1

and

Italian National Institute of Health

EIC/eRD14 Review Meeting

Sep / 19 / 2019

Why 2 talks on dRICH ?

We want to introduce our groups explicitly.

- Rome has been responsible of the design and performance analysis
- Ferrara/LNF have lots of fresh experience in large aerogel RICH design, construction and component procurements

- **Workforce**
- **Experience of INFN/Rome group**
- **dRICH Design**
- **MC Performances and optimization**
- **Key Components List**
- **Physics Events Reconstruction**

dRICH workforce

	People	WP (Specific Activities)	Available infrastructure
INFN/Ferrara	M. Contalbrigo (PI) L. Barion (PostDoc) Electronic service	**Test and validation** Component selections Project Management	Aerogel characterization facility Optical sensor characterization
INFN/LNF	M. Mirazita Mechanical Service	**Component selections** Test and validation (data analysis)	Mirror characterization facility
INFN/Rome	E. Cisbani + 2 Tech.	**Design and MC performance analysis** Test and validation (support prototype realization, carry on tests)	Gamma irradiation system
INFN/Catania	C. Tuvé + 1 Mech. Engineer	Test and validation (mechanical system)	Clean room
Duke	Z. Zhao	Design and MC performance analysis (MonteCarlo Physics)	

Contributing PostDocs (not in eRD14 recent/current funding requests)	
C. Fanelli (JLab/MIT)	Design and MC performance analysis (Design Optimization)
A. Del Dotto (LNF)	Design and MC performance analysis (Main analysis, support further development)
A. Movsisyan (INFN/Ferrara)	Test and validation (MC prototype performance)

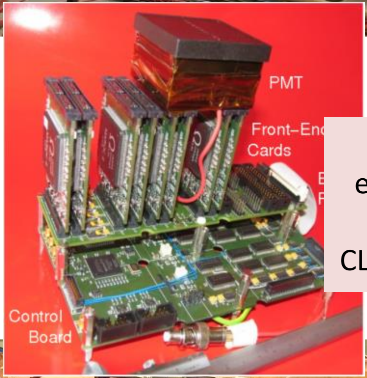
Rome Group Main Experience

- **RICHes**: (next 2 slides and Marco talk)
  - HERMES
  - Proximity Focusing @ JLab
  - Contributing to CLAS12/RICH*

*) active

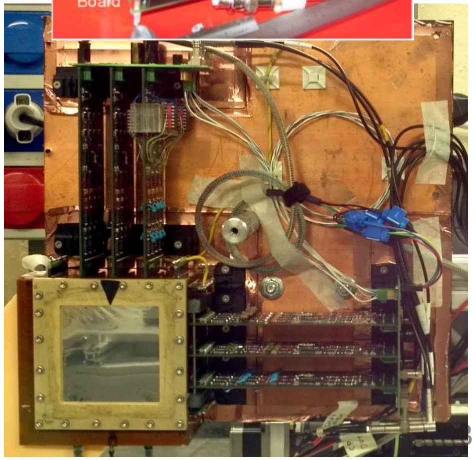
- **Charged Particles Tracking**:
  - HERMES Magnet Chambers (MWPC)
  - GEM Tracker for SBS*

- **Medical Imaging by Radionuclides:**
  - Compact Gamma Camera (based on MAPMTs)*



MAROC3 electronics
⇩
CLAS12/RICH

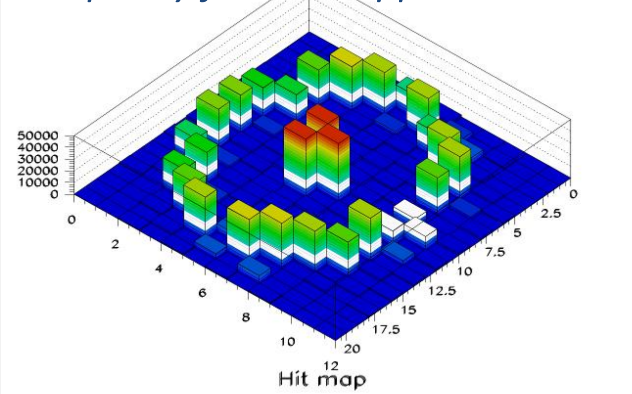
- **Proton Therapy:**
  - Dose Delivery Monitor (based on Ionization Micro Pattern Gaseus Detectors)*
  - Low energy proton irradiation facility*



Rome Group on RICH: First Aerogel tests and HERMES RICH

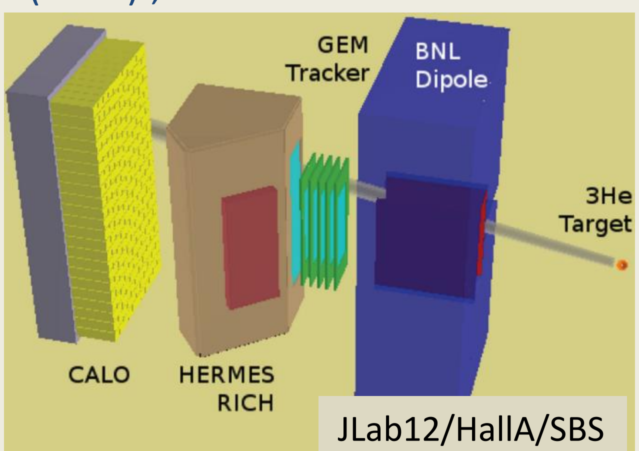
KEK Aerogel – π^- 10 GeV/c – Run 224

First evidence of adequate aerogel quality for RICH applications

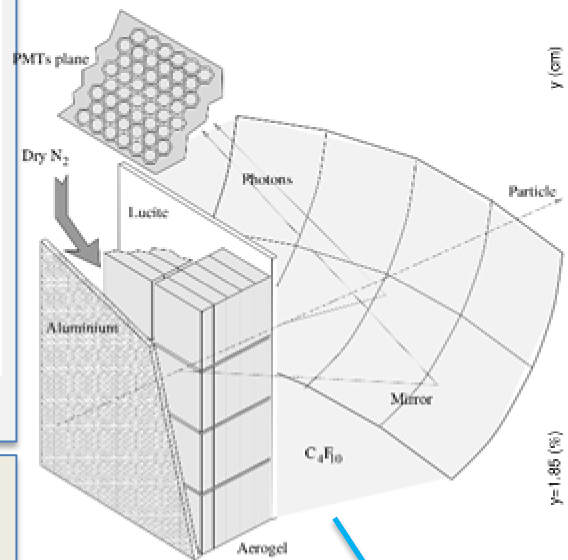


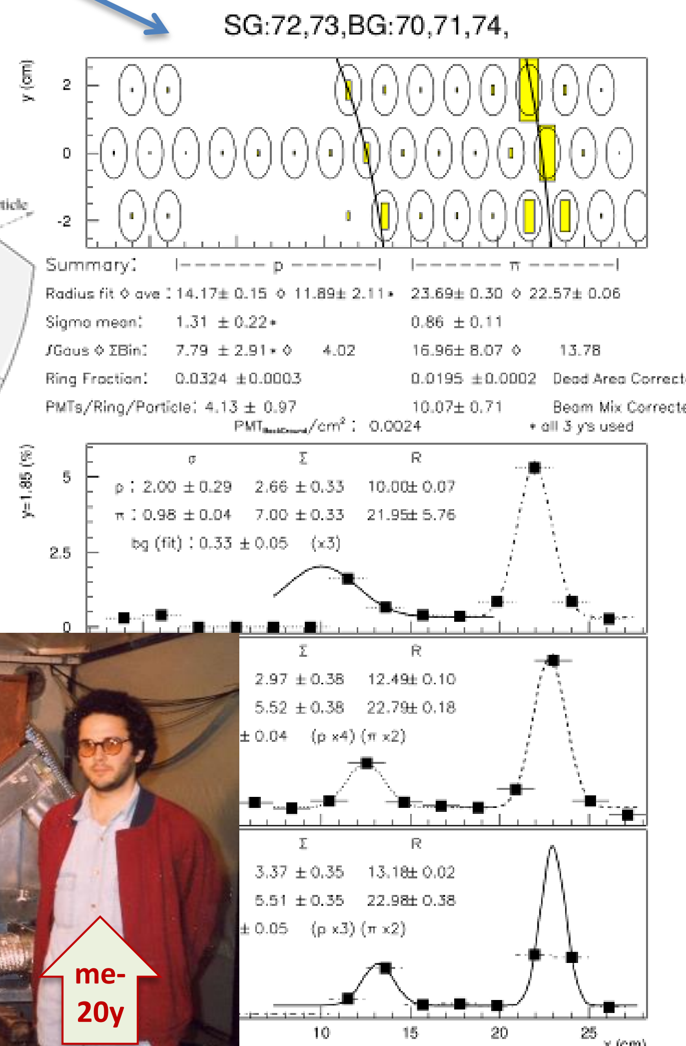
R. De Leo et al., NIM A401 (**1997**) 187

HERMES RICH successfully proposed for SIDIS exp. @ JLab (2008) ; then transferred to USA



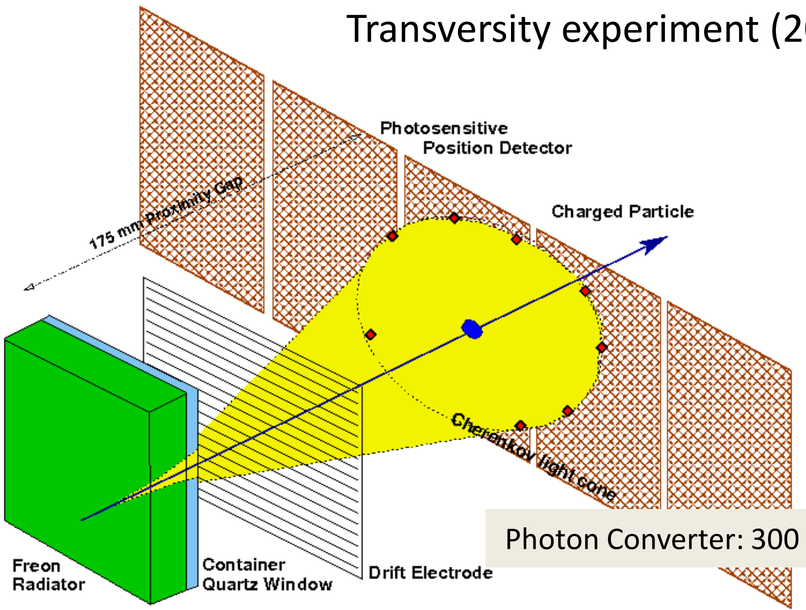
*Part of my PhD thesis (**1998**) : definition, simulation, readout electronics and <u>first beam tests</u> (at CERN) of the HERMES RICH*



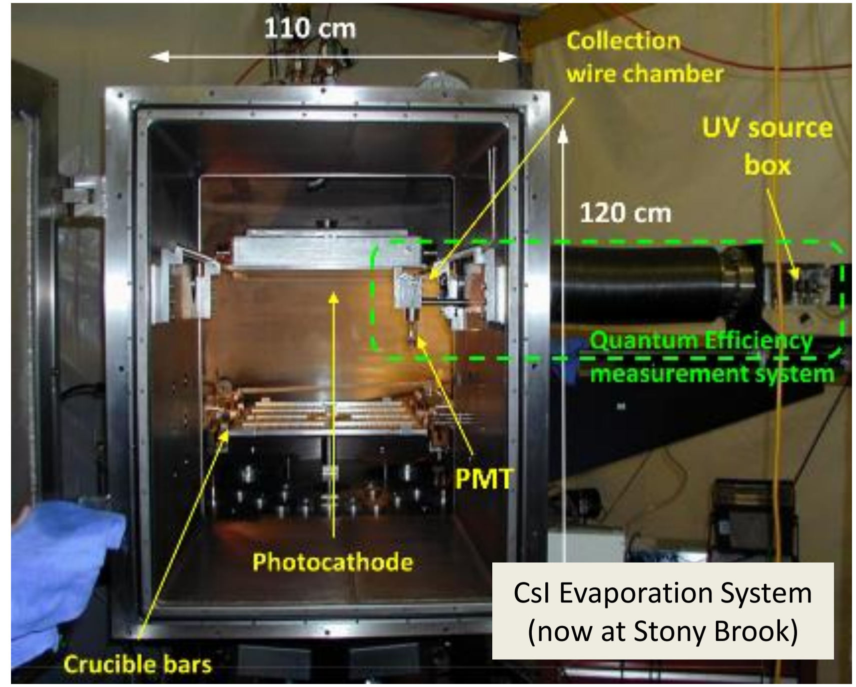


Rome Group on RICH: Proximity Focusing RICH @ JLab

Originally designed for Hypernuclear spectroscopy and then upgraded for the polarized 3He Transversity experiment (2008)

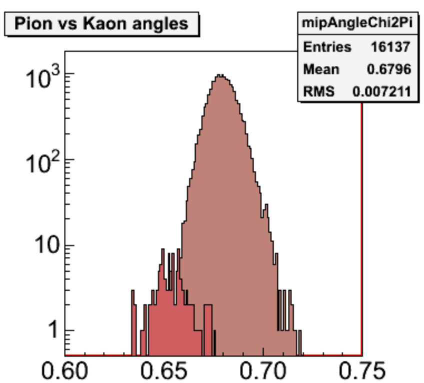


Photon Converter: 300 nm CsI

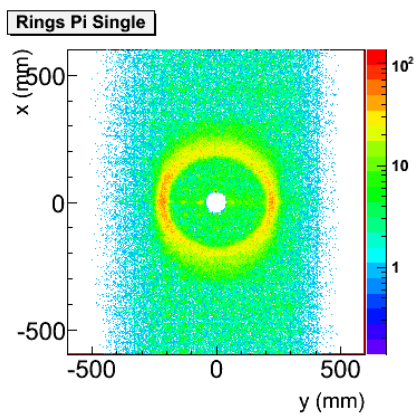


CsI Evaporation System (now at Stony Brook)

E. Cisbani et al. NIM A595 (2008) 44-46



P_h = 2.33 – 2.47 GeV/c



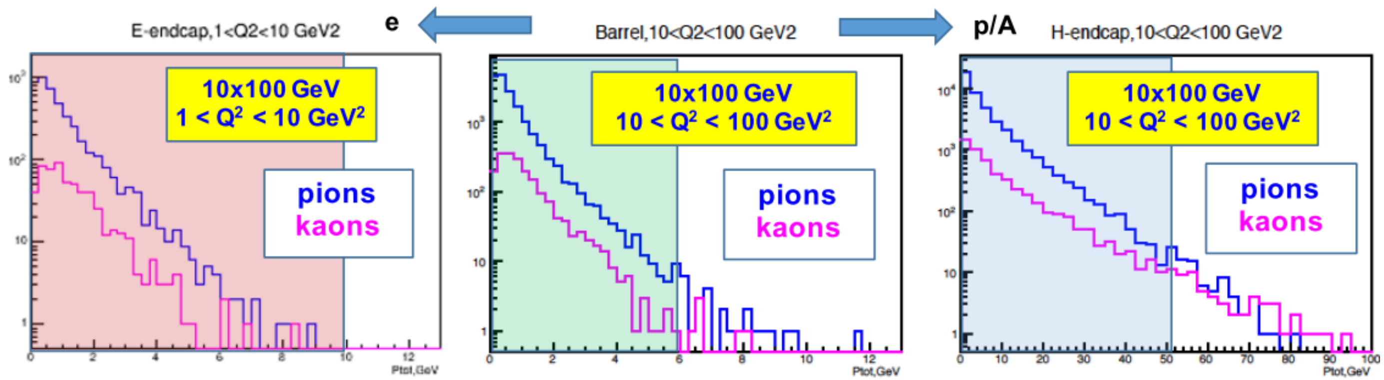
K/π separation at 3.8σ

Detector designed and built in Rome

Hadron-ID @ EIC h-endcap

“Simulations show that in order to satisfy the physics goals of the EIC, it is desirable to provide π/K identification in the central barrel up to 5-7 GeV/c, in the electron-going endcap up ~10 GeV/c, and **in the hadron-going endcap one would need to reach ~50 GeV/c**.”, from the “Electron-Ion Collider Detector Requirements and R&D Handbook”, January 10, 2019

- SIDIS
- 3D tomography
- Diffraction
- Gluon saturation
- Open charm



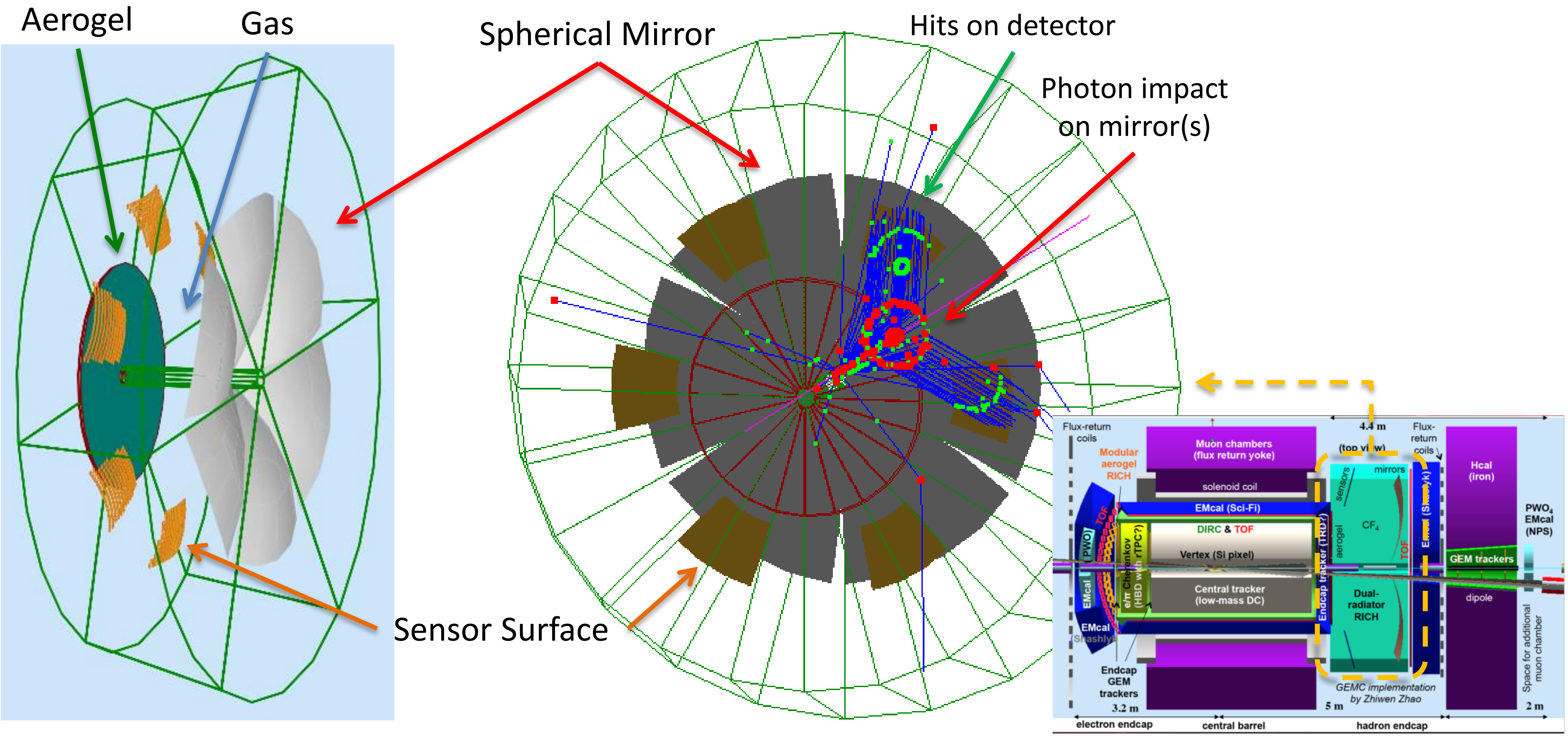
Physics Requirement:

1. **Continuous *π/K/(p) identification up to ~50 GeV/c* in hadron endcap**

Main Technological Requirements:

2. **Geometrical constraints (relatively small longitudinal space and large transverse space)**
3. **Solenoid Magnetic Field**
4. **Radiation levels**

dRICH in EIC - baseline model



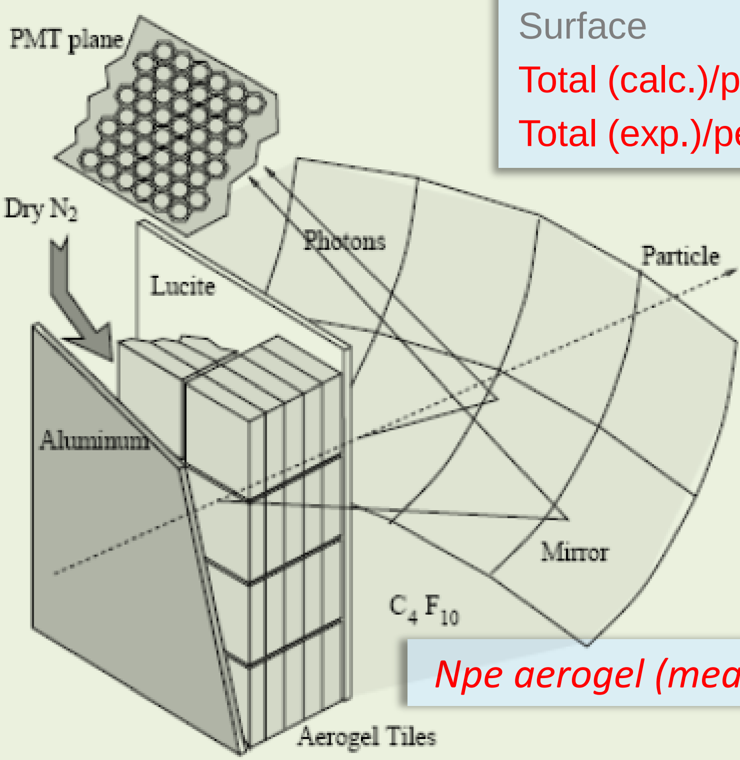
- Radiators: Aerogel (4 cm, $n_{(400nm)}$~1.02) + 3 mm acrylic filter,
  Gas (1.6 m, n_{C2F6}~1.0008)
- 6 Identical Open Sectors (Petals):
  - Large Focusing Mirror with R ~2.9 m
  - Optical sensor elements: ~4500 cm^2/sector, 3 mm pixel size, UV sensitive, out of charged particles acceptance

Advantages:
- Full momentum, continuous coverage
- Relatively simple geometry/optics
- Expected to be Cost Effective (respect to 2 x detectors solution)

Dual radiator aerogel-gas RICHes so far

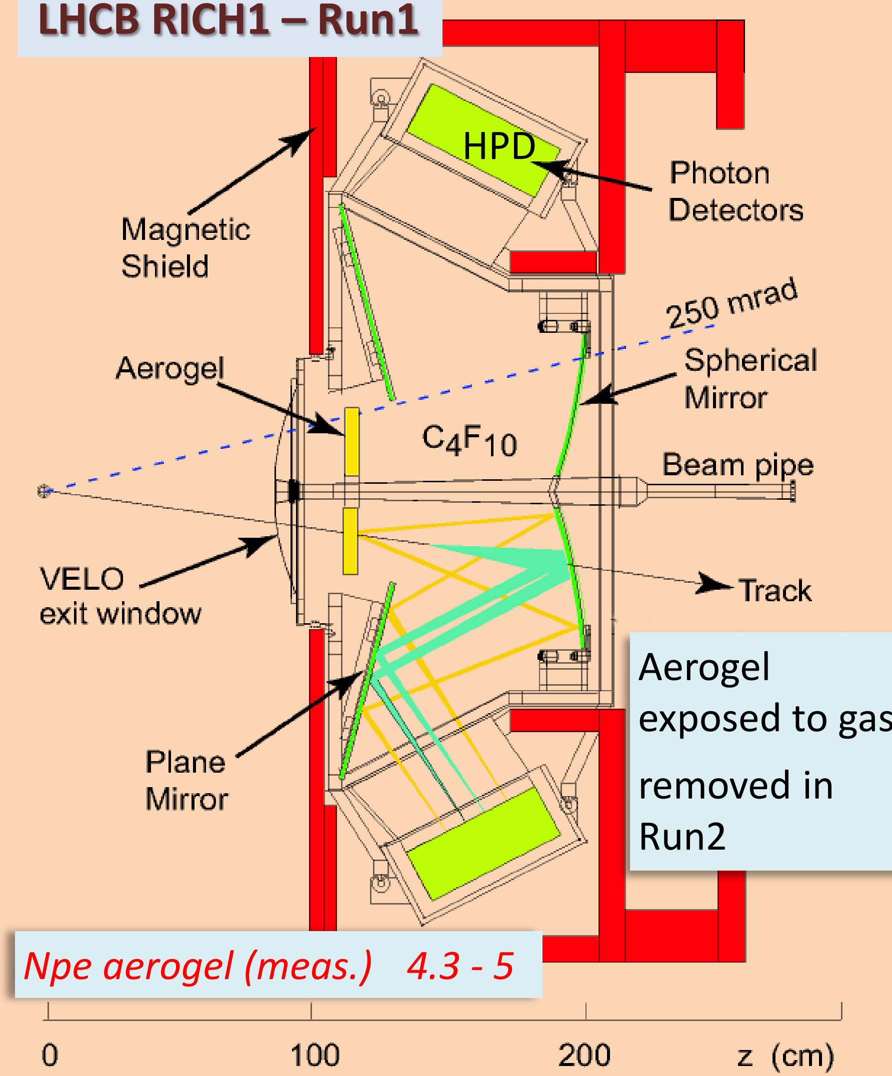
HERMES RICH

Angular resolution	
Pixel	2.3
Chromatic	1.3
Point emiss.	0.7
Mirror	0.6
n spatial disp.	0.5
Forw. scatt.	0.4
Surface	0.4
Total (calc.)/pe	2.9
Total (exp.)/pe	3.3



Npe aerogel (meas.) ~10

LHCB RICH1 – Run1

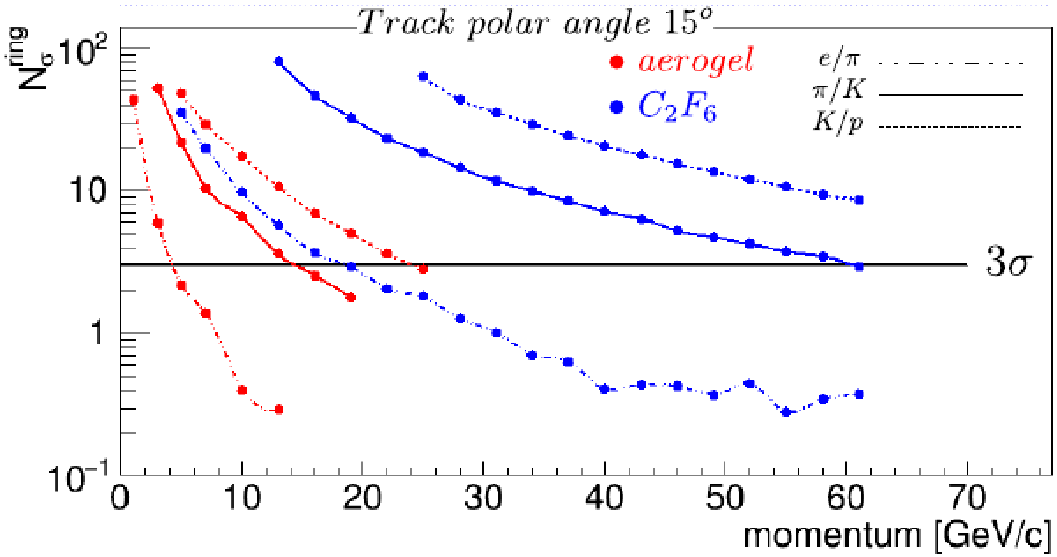


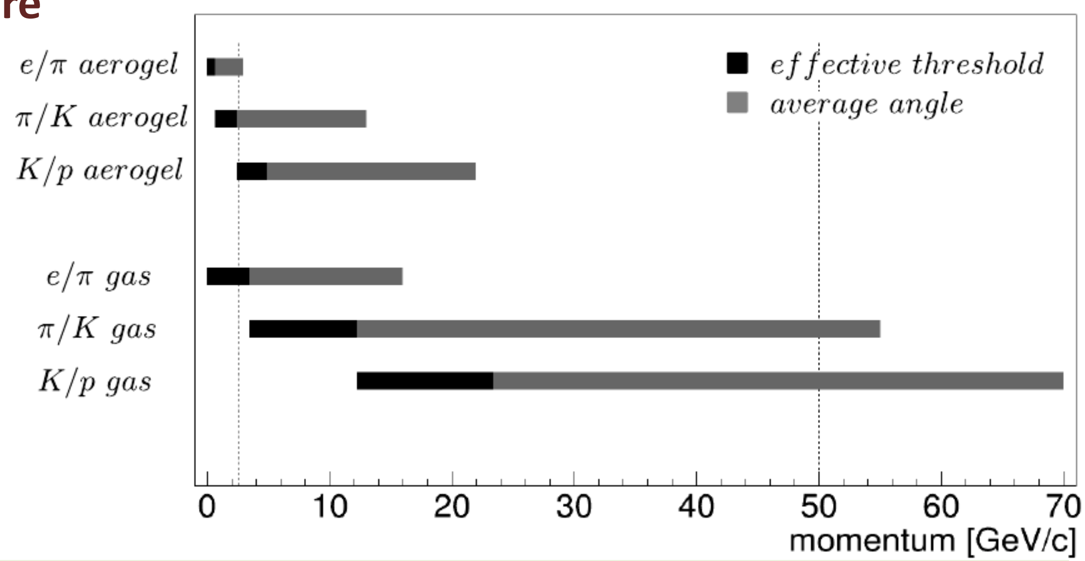
Aerogel exposed to gas; removed in Run2

Npe aerogel (meas.) 4.3 - 5

dRICH baseline MC performance

- Montecarlo: GEMC (Geant4)
- Aerogel Optical properties from CLAS12 RICH data, scaled to 1.02
- Acrylic Filter (<300nm) after the aerogel to minimize Rayleigh
- Gas number of photons normalized by 0.7 factor from «poor» literature
- Include 3T central magnetic field
- Mirror quality from CLAS12
- QE from realistic CLAS12/PMT measurements (200-500 nm)
- Cherenkov Angle reconstruction based on Inverse Ray Tracing



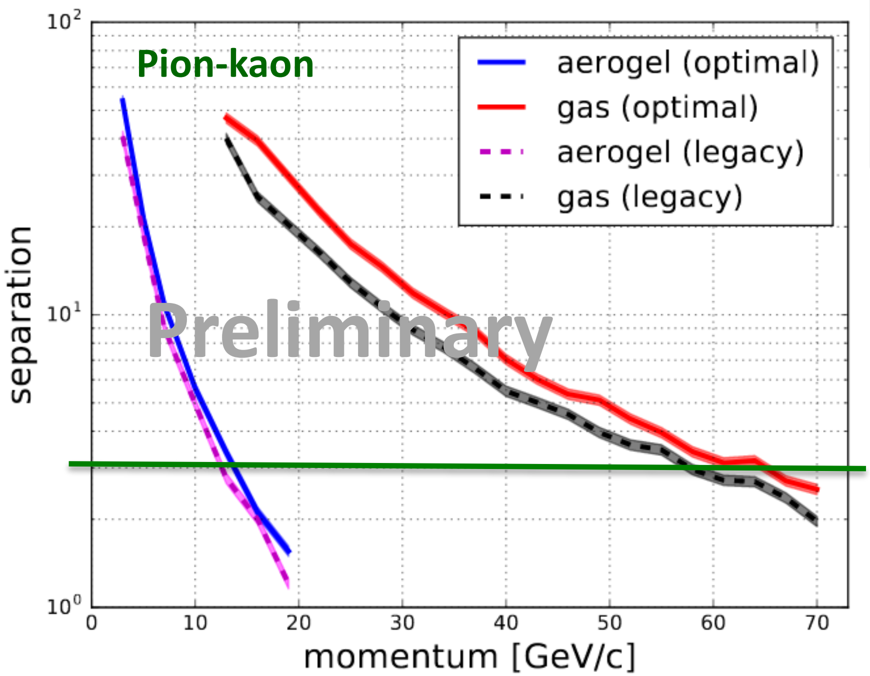


Hadron identification (π/K/p, better than 3 sigma apart); continuous coverage from ~3 up to ~50 GeV/c for π/K and up to ~15 GeV/c for e/π

dRICH Performance Optimization

- Combine detailed MonteCarlo simulations with **Bayesian Approach** to efficienty maximize a proper Figure of Merit (π-K Cherenkov angles separation in critical phase spaces regions, e.g. TOF-aerogel and aerogel-gas transitions, high momentum limit …)
- Latest implementation use 8 independent parameters →

parameter	**description**	**range** [units]
R	mirror radius	[290.0,300.0] [cm]
pos r	radial position of mirror center	[125.,140.] [cm]
pos l	longitudinal position of mirror center	[-305.,-295.] [cm]
tiles y	shift along y of tiles center	[-5,5] [cm]
tiles z	shift along z of tiles center	[-105,-95] [cm]
tiles x	shift along x of tiles center	[-5,5] [cm]
$n_{aer.}$	refraction index of aerogel	[1.015,1.03]
$t_{aer.}$	aerogel thickness	[3.0,6.0] cm



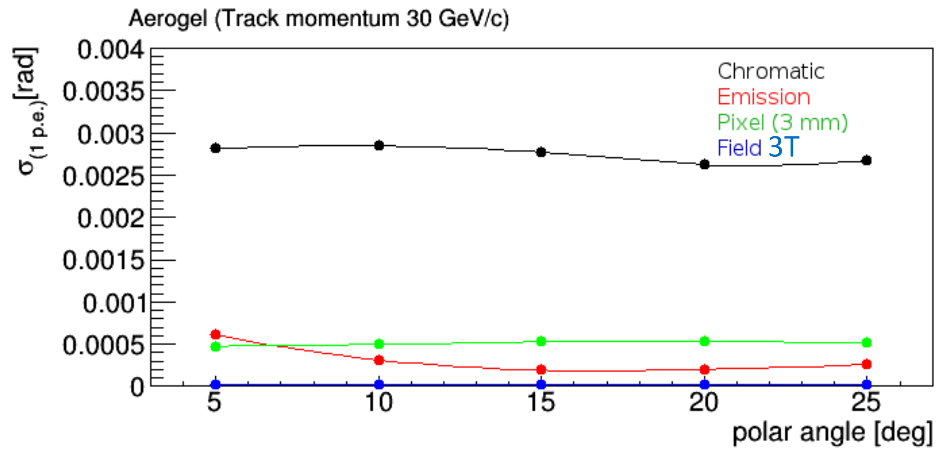
- The optimization approach can be ported to any detector development where a detailed MonteCarlo exists and/or there are significant amount of real data
- **Validated MonteCarlo is essential to get realistic results → prototype needed**

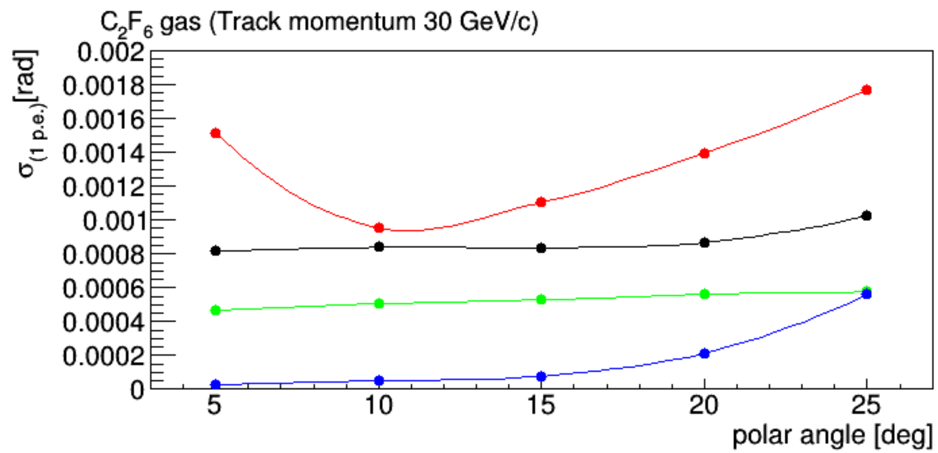
dRICH – Single Photon Angular resolution

All the main contributions to the Cherenkov angle resolution have been evaluated by MC

Largest effects from

- Aerogel chromatic
  variation of refractive index with wavelength
- Gas emission
  unknow emission position of the photons, sensor surface and reconstruction; chromatic contribution follows closely (potential scintillation not included)





dRICH demands for excellent and stable performance from aerogel (and gas) radiator(s) and their interplay!

dRICH key hardware components

Component	Function	Specs/Requirements	Critical Issues / Comments
Aerogel Radiator	Cover Low Mom. Range between TOF and Gas	$\geq 3\sigma$ π-K separation up to Gas region (~13 GeV)	Procurement: currently 1 active provider (2 main producers) **Performance and long term stability assessment need adequate studies**
Gas Radiator	Cover High Mom. Range from Aerogel	$\geq 3\sigma$ π-K separation up to ~50 GeV and overlap to aerogel	**Real performance assessment needed**; final gas system needs adequate design, to keep pressure and purity under control; technically feasible
Optics (Mirrors)	Focus (expecially for gas) and deflect photons out of particle acceptance and reduce sensor surface	$\sigma_\theta \leq 1$ mrad, reflectivity $\geq 90\%$, material budget	Spherical mirrors technology of CLAS12 suitable (optical fiber and/or glass skin); similar geometry; development can be carried on for cost reduction
Photon Detector	Single photon spatial detection	Magnetic field tolerant and radiation hardness; ~few mm spatial resolution	**MCP-PMT is likely doable, but expensive, solution**. MCP improvement is ongoing; LAPPD may represent an alternative. SiPM is a promising, quicky improving, wordwide interest, and chip technology
Electronics	Amplify and shape single photon analog signal, convert to digital, transfer to DAQ nodes	Low noise, time res. ~ 0.5 ns μs signal latency	MAROC3 based readout available for prototyping; final choice will depend on sensor. Ongoing electronics development within the consortium and wordwide
Mechanics	Support all other components and services Keep in position and aligned	Large volume gas and light tightness; alignment of components	Technically demanding but feasible; no major challenges expected

Event Based Reconstruction – baseline for physics

~40% of PYTHIA/DIS events have multiple tracks in dRICH

~50% of them with overlapping rings;

Track based Inverse Ray-Tracing

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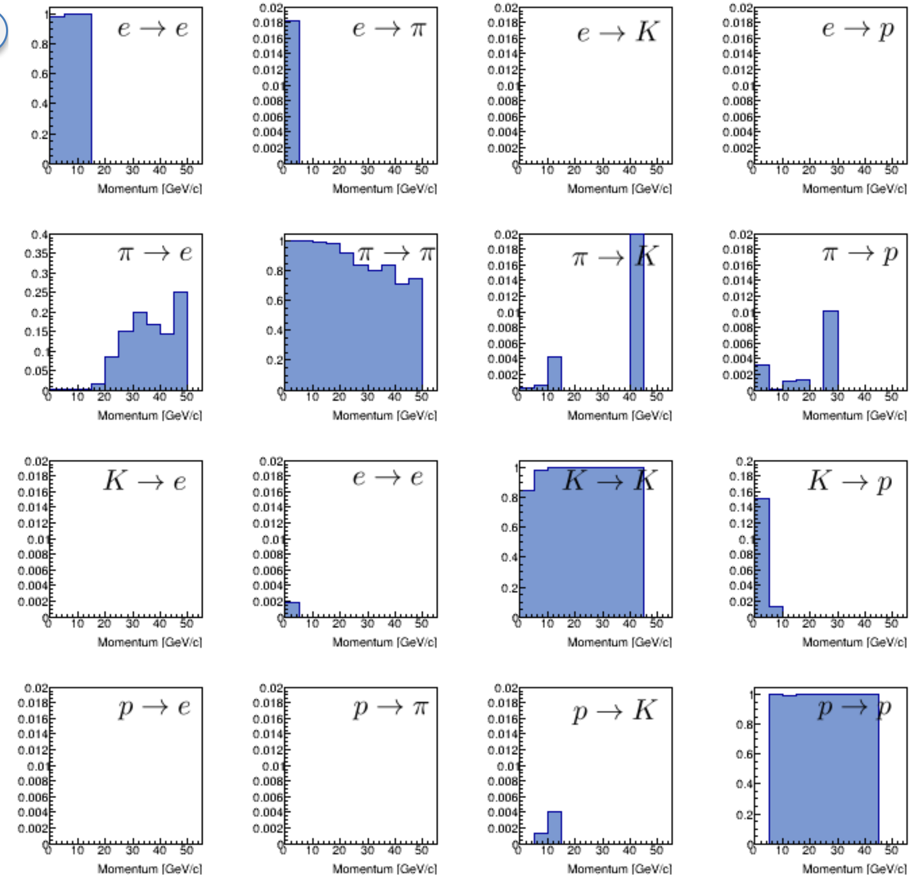
π/K contamination > 10%

Developed an efficient event based reconstruction method: use two-steps (two Likelihood functions) approach to reduce significantly the computational efforts.



Example: event with 2 tracks and 15 hits

Brute Force: up to **~488 billion** combinations
Our approach: **1200** combinations

Reconstruction essential to get physics results; **proposed method exploitable in the future EIC analysis framework**; alternatives will also be explored

Summary - design and performance

- Consolidated baseline of the dRICH design exists:
  - Hardware: all major components identified
  - Software: GEMC Montecarlo and event based PID implemented
- Detailed MC performance evaluation confirms fulfillment of EIC physics requirement; further optimizations ongoing using Bayesian approach, a general method that can be applied to other detectors.

→ *need realistic validation (and evaluation of technical details that cannot be modeled by Montecarlo)*

→ *need cost optimization by carefull selection / customization / test of major critical components*