Upgrade of the Proximity Focusing RICH at JLab

E. Cisbani

Istituto Superiore di Sanità and INFN Roma, Sanità group

RICH2007
15-20 October 2007, Trieste - Italy

JLab RICH People

Istituto Superiore di Sanità and INFN Roma, Sanità group

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Funded by INFN (LEDA experiment) and JLab

Outline

- **Introduction**
  - **JLab RICH**
  - **JLab facility**
- Past: Original RICH version
  - Performed experiment(s)
  - Measured performance
- In progress: Upgraded RICH version
  - Motivation: Transversity experiment
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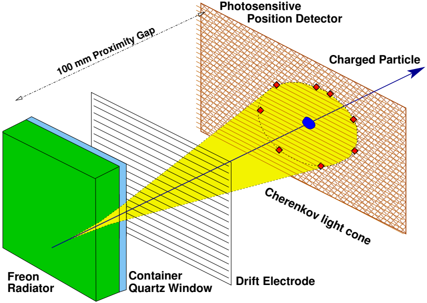
Proximity Focusing RICH @ JLab

Conceptually identical to the Alice HMPID RICH



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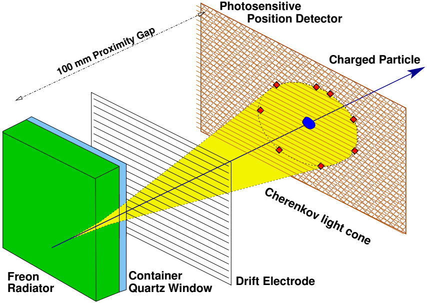

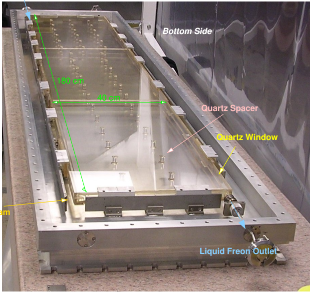

Radiator 15 mm thick Liquid Freon (C_6F_{14}, n=1.28)

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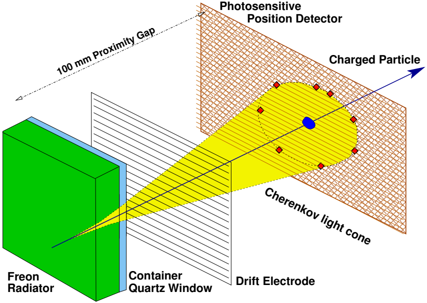

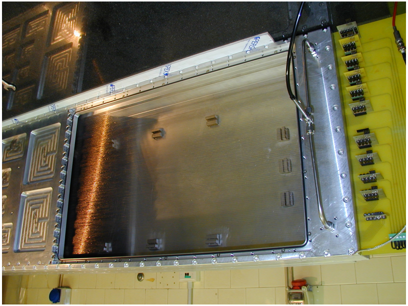

Radiator	15 mm thick Liquid Freon (C_6F_{14}, n=1.28)
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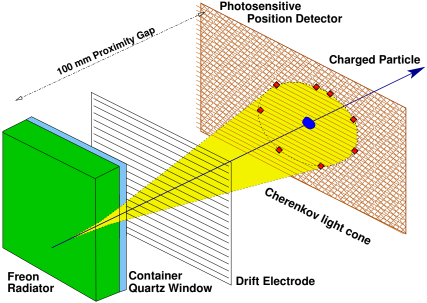

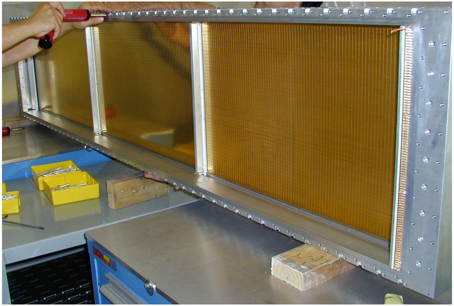

Radiator	15 mm thick Liquid Freon (C_6F_{14}, n=1.28)
Proximity gap	100 mm, filled with Methane at STP
Photon converter	300 nm CsI film evaporated on each pad plane
Position detector	$3 \times$pad plane $= 1940 \times 403$ mm^2
	Multi Wire/Pad Proportional Chamber, HV$= 1050 \div 1100$ V
Pad Plane	403.2×640 mm^2 (single pad: 8.4×8 mm^2)

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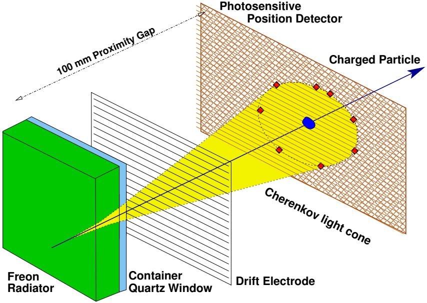

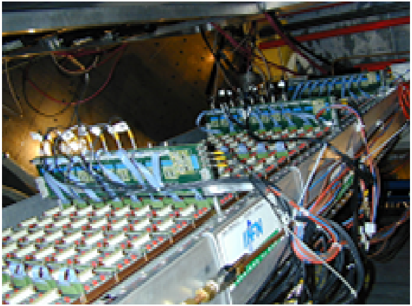

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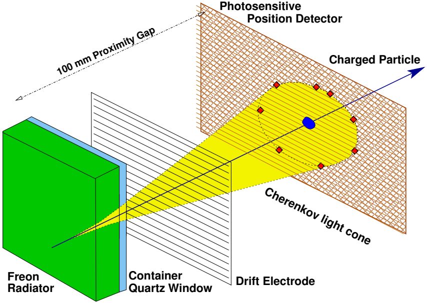

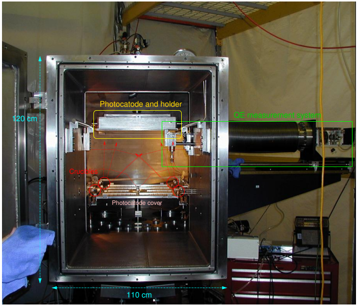

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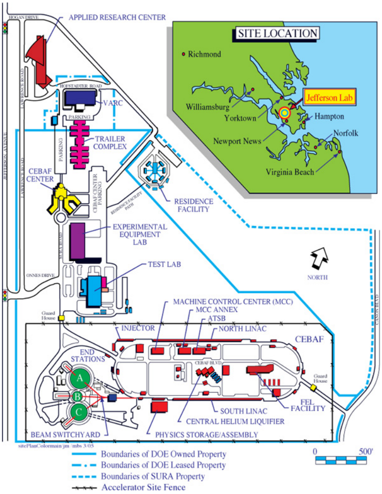
Evaporation Fac.	Cyl. vacuum chamber + Online QE measurement

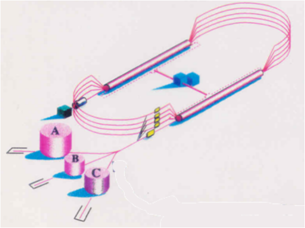
The Continuous Electron Beam Accelerator Facility



JLab, Newport News (VA)

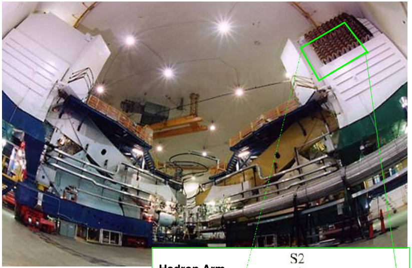
The *high resolution and high luminosity* (polarized) CEBAF electron beam:

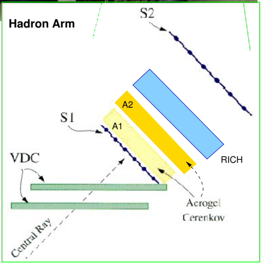
- Current: up to 200 μA
- Energy: up to 6 GeV (12 GeV in 2012)
- Energy resolution (σ_E/E): 2.5×10^{-5}
- Duty factor: 100% (continuous beam)
- 3 Experimental halls: A, B and C



Hall A Detection Equipment

Flexible detectors configuration depending on experiment





HRS + Septum

$\vartheta_{min} = 6°$

$\Delta\vartheta\Delta\phi \sim 5$ msr

$p_{max} = 4$ GeV/c

dp/p = 5%

$\Delta p/p \sim 10^{-4}$ (FWHM)

$\Leftarrow$ 2 High Resolution Spectrometers (QQDQ) + 2 Septum Magnets (for angles down to 6 degrees)

BigBite: High Acceptance Spectrometer

The Hadron Arm

- Trigger: 2 scintillators
- Tracking: 2 Drift Chambers
- e-h PID: Gas Cherenkov Counter + Preshawer
- standard h-PID: 2 Aerogel Čerenkov (1.055 and 1.015 for $p/K^+/\pi^+$ on-line separation up to $\sim$ 2.2 GeV/c)
- Enhanced h-PID:
  Proximity focusing RICH

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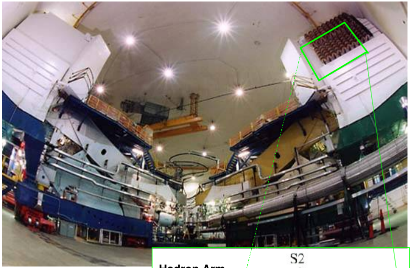

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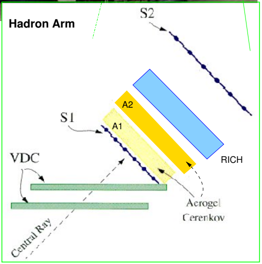

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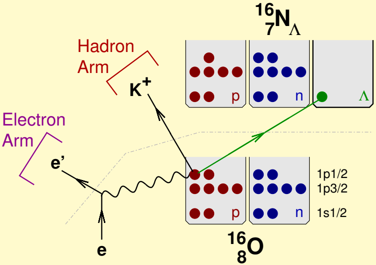
Systematic study of hypernuclei by electromagnetic probe



- Λ is a unique **probe** in the nucleus
- Λ can be in the s-shell (no Pauli blocking)
- Λ weakly coupled to nuclear core $\rightarrow$ shell model works well
- Λ−N potential:
  $V_{\Lambda N} = V + \Delta + s_\Lambda + s_N + T$
- $^9Li_\Lambda$,$^{12}B_\Lambda$ and $^{16}N_\Lambda$ investigated

Measure hypernucleus excitation energy to extract information on $\Lambda - N$ potential

k-PID Requirement (Momentum $\sim$ 2 GeV/c)

Signal ($(e, e'K)$ bound state) $\sim 10^{-3} \div 10^{-4}$ Hz
Background (π and p mainly) $\sim 100 \div 1000$ larger than K
Standard Hall A (A1 & A2) π:K rejection factor $\sim 1 : 100$

1:10 at least still needed $\Rightarrow$ RICH !

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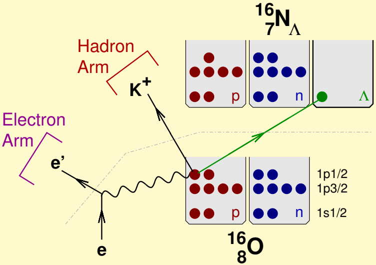

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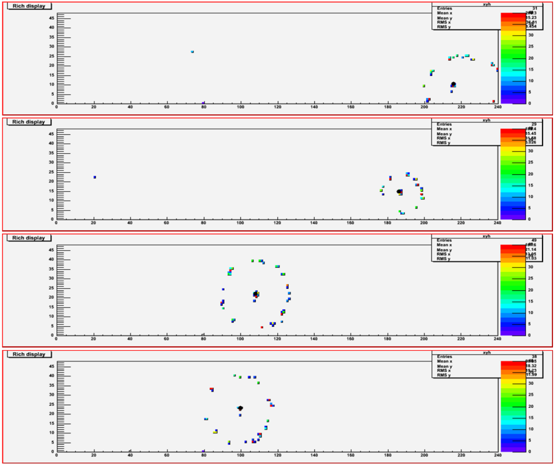
Online Event display

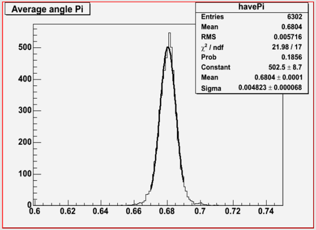


Charge particles mutiplicity (20% of events with 2 particles)

$\Rightarrow$ rather clean event pattern

Original RICH performance at $2.0 \pm 5\%$ GeV/c

Hyper. Exp. Data

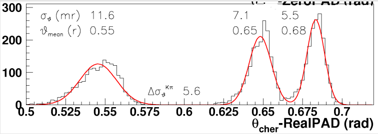


Mean Hits (for π): $N_{PAD,\pi} = 13$

Angle resolution: $\sigma_{\theta_\pi} = 5$ mrad

$$\rightarrow \Delta\theta_{\pi,K} = 6\sigma_{\theta_\pi}$$

GEANT3 MonteCarlo



Pretty good agreement between experimental data and MC:

$$\sigma^{EX}_{\theta_\pi} / \sigma^{MC}_{\theta_\pi} \sim 0.9$$

$$N^{EX}_{PAD,\pi} / N^{MC}_{PAD,\pi} \sim 0.9$$

$$\Delta\theta^{EX}_{\pi,K} / \Delta\theta^{MC}_{\pi,K} \sim 1.07$$

$\Rightarrow \pi/K$ rejection better than 1:1000

Original RICH performance at 2.0 ± 5% GeV/c

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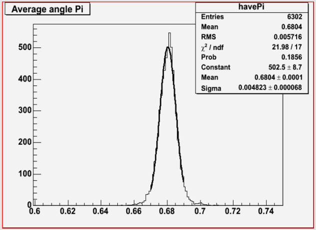

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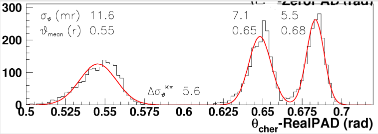

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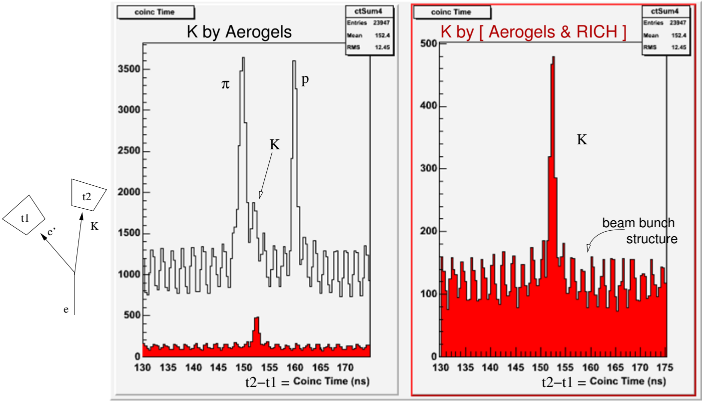
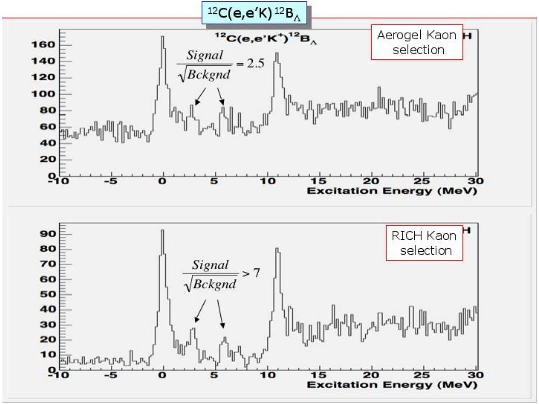


- Time of Flight (FWHM $\sim$ 850 ps)
- Aerogels: $(!A_{1.015})\&A_{1.055}$
- **RICH**

Kaon PID



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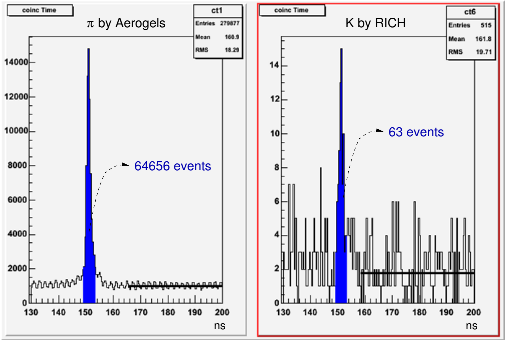
Effect on Excitation Energy SNR

Pion rejection



1. select pions by aerogels: $A_{1.015} \& A_{1.055}$ $\rightarrow N_{\pi}^{AERO} = 64656$
2. then select K by RICH on the above sample $\rightarrow N_{K/\pi}^{RICH} = 63$

RICH Pion Rejection Factor $> \frac{N_{K/\pi}^{RICH}}{N_{\pi}^{AERO}} \sim$ **1:1000**

at ~ 90 % efficiency

Note: Measured Signal/Background rate meets optimistic expectation ($\sim$ 10 times better than worst prediction)

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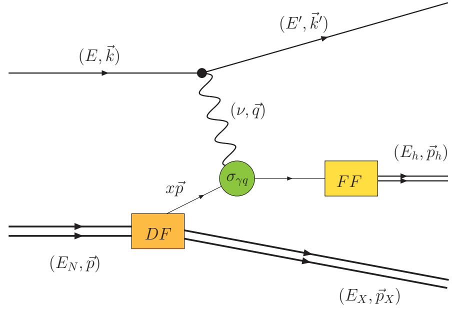
SIDIS Transversity Experiment

Investigate the spin structure of the nucleon by: $N^{\uparrow}$(e,e'h)X in DIS



Kinematics DIS Region

$$Q^2 = -(\nu,\vec{q})^2 \quad \gg M^2$$
$$\nu \overset{lab}{=} E - E' \quad \gg M$$
$$x = Q^2/(2M\nu) \quad > 0, < 1$$
$$z = E_h/\nu$$

scale	lepton probe	strong interaction
space	$\hbar/\lvert\vec{q}\rvert \sim 10^{-2}$ fm	$R_N \sim 1$ fm
time	$\hbar/\nu \sim 10^{-25}$ s	$R_N/c \sim 10^{-24}$ s

Factorization Theorem

$$\sigma(eN \to ehX) \sim \sum_q e_q^2 \cdot DF_q(x) \otimes \sigma_{lq} \otimes FF_{q\to h}(z)$$

DF_q: quark Distribution Functions

$FF_{q\to h}$: quark Fragmentation Functions

$k_\perp$ Dependent (TMD) Quark DF at Twist-2

	Nucleon			
Quark	0	L	T	
0	$f(x, k_\perp)$		$f_{1T}^\perp(x, k_\perp)$	
L		$g_{1L}(x, k_\perp)$	$g_{1T}(x, k_\perp)$	
T	$h_1^\perp(x, k_\perp)$	$h_{1L}^\perp(x, k_\perp)$	$h_{1T}(x, k_\perp)$	$h_{1T}^\perp(x, k_\perp)$

$\int dk_\perp f(x, k_\perp)$ unpolarized DF, very well measured
$\int dk_\perp g_{1L}(x, k_\perp)$ longitudianl DF, well measured
$\int dk_\perp (h_{1T} + k_\perp^2/(2M) h_{1T}^\perp)$ Transversity DF, first evidence (leading order DF)
$f_{1T}^\perp(x, k_\perp)$ Sievers DF (info on quark angular momentum)

$k_\perp$ Dependent (TMD) Quark DF at Twist-2

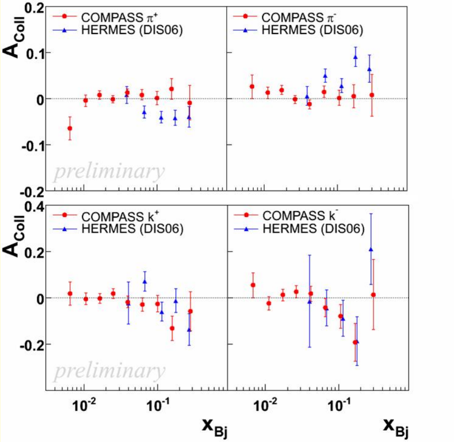
Quark	Nucleon 0	Nucleon L	Nucleon T
0	$f(x, k_\perp)$		$f_{1T}^\perp(x, k_\perp)$
L		$g_{1L}(x, k_\perp)$	$g_{1T}(x, k_\perp)$
T	$h_1^\perp(x, k_\perp)$	$h_{1L}^\perp(x, k_\perp)$	$h_{1T}(x, k_\perp)$ $h_{1T}^\perp(x, k_\perp)$

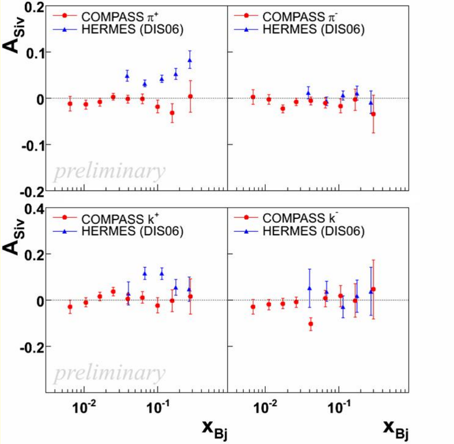
Trasversity and Sievers investigated via Single Spin Asymmetry measurement by DIS on trasversely polarized target:

$$A_{UT}(\phi_h^l, \phi_S^l) = \frac{d\sigma^\uparrow - d\sigma^\downarrow}{2d\sigma} \sim A_{UT}^{\text{Collins}} sin(\phi_h^l + \phi_S^l) + A_{UT}^{\text{Sivers}} sin(\phi_h^l - \phi_S^l)$$

Present Data

HERMES(DIS06) on proton / COMPASS(ETC07) on deuteron





- K asymmetries look relevant
- No direct data on neutron

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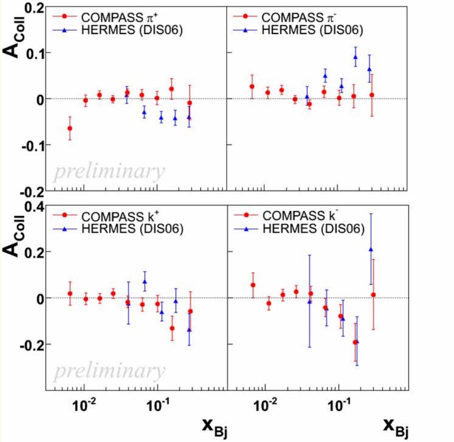

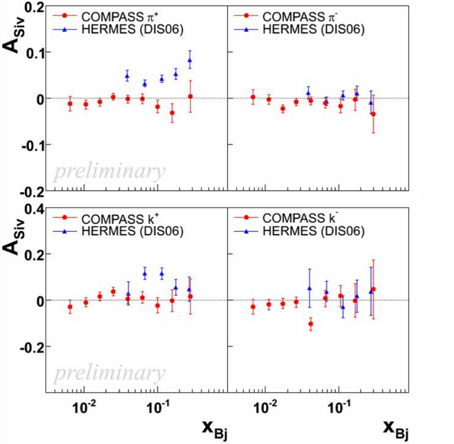

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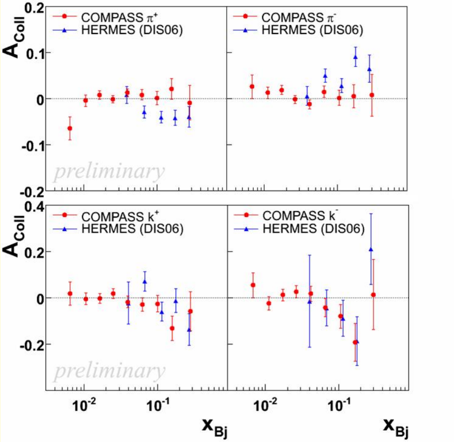

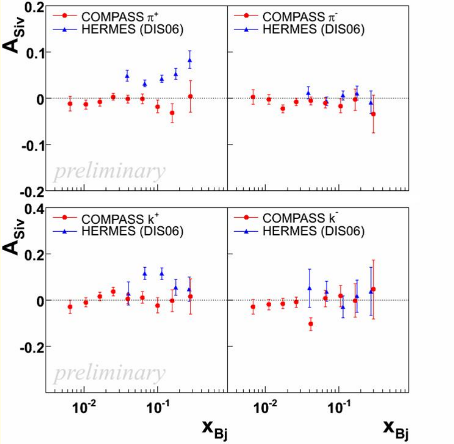

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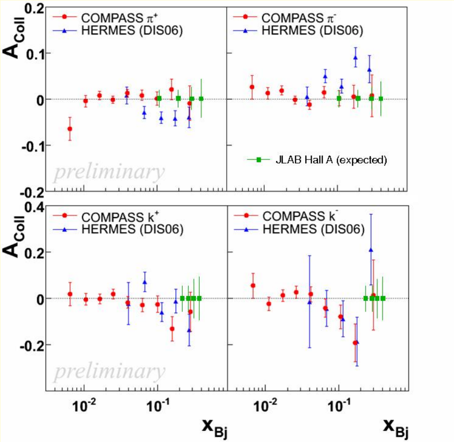
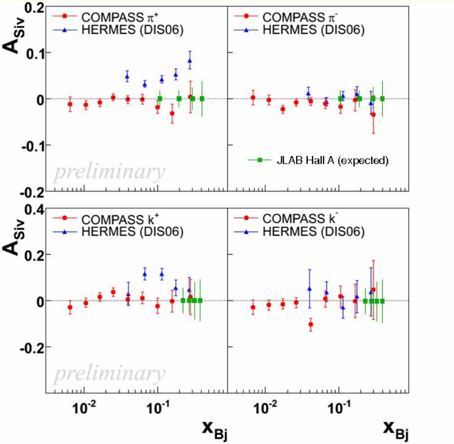
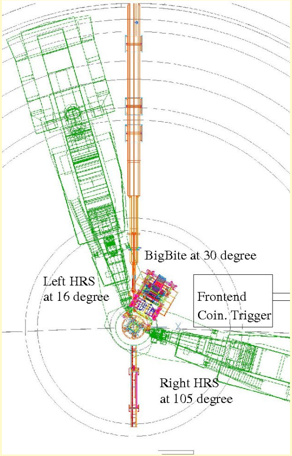
HERMES on p / COMPASS on d / JLab on neutron (proj. errors)





1 month data taking:
statistical errors comparable to HERMES(3 years)/COMPASS(2 years)

Transversity: Hall A Experimental Setup



Beam

6 GeV, 15 μA e^- (target limit)

Target

High pressure polarized ^{3}He, 50 mg/cm^2, $\sim$ 42% polariz./20 min, Lumi $\sim 10^{36}$/s/cm^2

Electron Detection: BigBite

$E' = 0.8 \div 1.9$ GeV, $\theta = 30^o$, $\Delta\Omega \sim 64$ msr

Hadron Detection: HRS Left

$P_h = 2.4$ GeV/c, $\theta = -16^o$, π/K ID

Data taking

30 beam days, Summer 2008

Kinematic Region

$\langle Q^2 \rangle = 2.2$ GeV^2, $x = 0.13 \div 0.4$, $z \sim 0.5$

RICH Upgrade

Traaversity Requirement: $\pi : K$ **rejection** $\sim$ **1:1000 at 2.4 GeV/c**

Old RICH at 2.4 GeV/c: $\Delta\theta \sim 4.1\sigma \Rightarrow \pi : K \sim 1 : 140$

Upgrade Options

1. New Radiator: from C_6F_{14} ($n = 1.28$) to C_5F_{12} ($n = 1.24$): lover index of refraction means smaller angles (improved photon acceptance), larger angular distance between kaon ad pion photons.
   - Liquid freon re-circulation system to be modified
   - C_5F_{12} boils at 29°C → more complex liquid radiator system
   - C_5F_{12} one of the worse greenhouse gases → pure C_5F_{12} is very expensive (isomeric mixture much cheaper ... but transparency?
2. Larger photon detector (and longer gap): high photon acceptance, smaller geometric and digitization errors
   - $\sim 1/2$ of the detector structure must be rebuilt
   - Additional electronics needed (we already have!)
   - Upgrade is 'straightforward'

Costs and tight time schedule ⇒ second option

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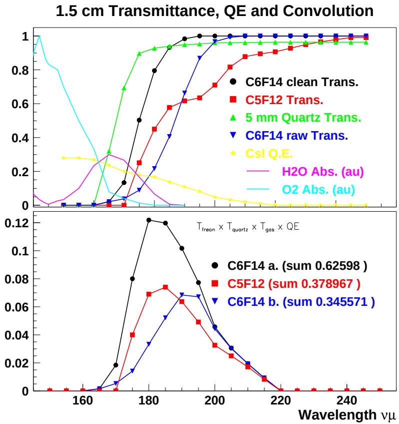
Isomeric C_5F_{12} Freon Transparency



- Iso-C_5F12 shows $\sim 1/2$ the transmittance of clean C_6F_{14}
- Air (H_2O) contamination in Iso-C_5F_{12} sample looks significant (but does not explain full absorbtion)
- Transparency could improve with proper cleaning but not guaranteed
- Structure in transmittance may be related to other contaminats (?)
- Extrapolation may suggest $\sim 1/3$ transmittance loss (respect to C_6F_{14} after cleaning

(Thanks to A. Bream for C_5F_{12} and A. Di Mauro for C_6F_{14} data)

- Iso-C_5F_{12} transparency requires further investigation (not compatible with experiment schedule)

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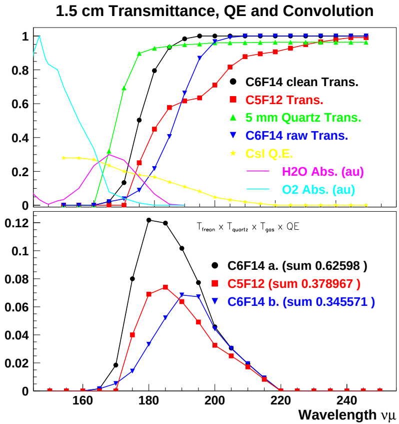

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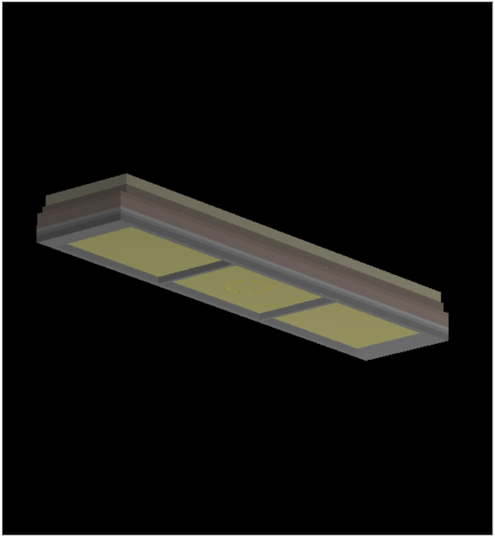
From Original to Upgraded RICH



- The JLab RICH is a sandwich of several layers
- Preserve the radiator, entrance Al frames and grid plane
- Rebuild the last 3 Al frames + wires planes
- Use the same pad planes 90°rotated
- Obtain a photon detection area 1.6× larger than original
- … and 175 mm far from the radiator

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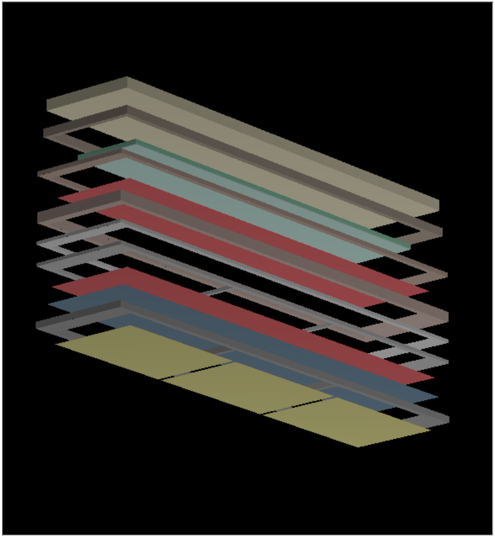

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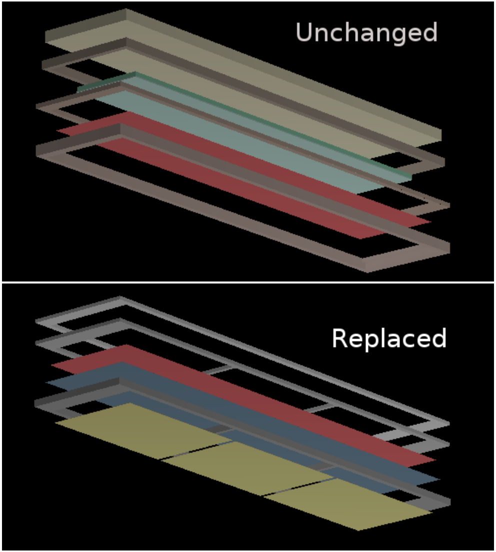

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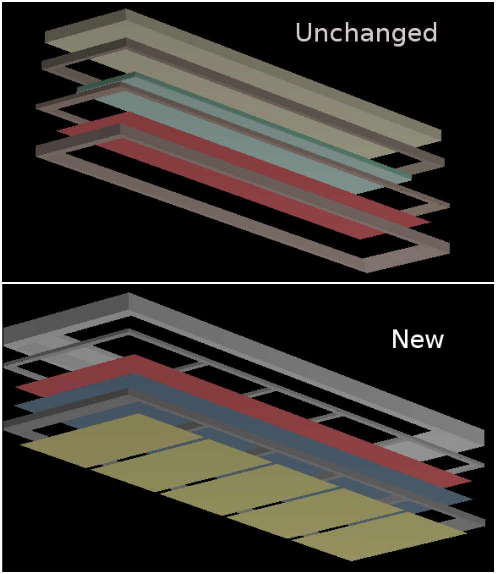

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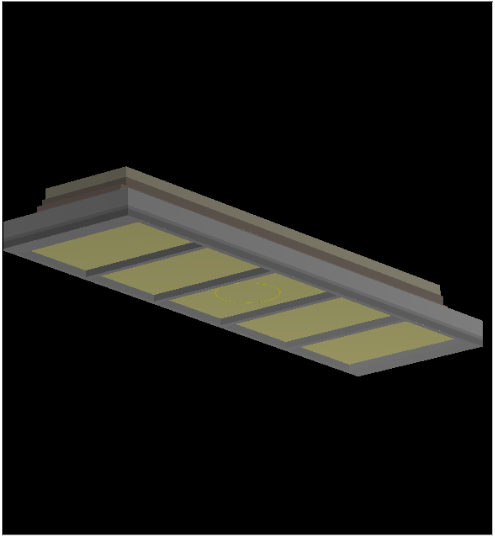

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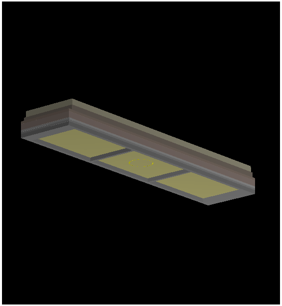
Upgraded Proximity Focusing RICH @ JLab



⇒

Radiator	15 mm thick Liquid Freon (C_6F_{14}, n=1.28)
Proximity Gap	100 mm, filled with Methane at STP
Photon converter	300 nm CsI film coated on Pad Planes
Position Detector	3× pad planes = 1940×403 mm^2
	Multi Wire/Pad Proportional Chamber, HV= 1050 ÷ 1100 V
Pad Plane	403.2×640 mm^2 (single pad: 8.4×8 mm^2)
FE Electronics	11520 analog chs, multiplexed S&H

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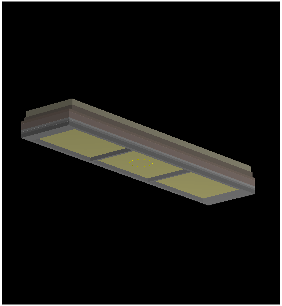
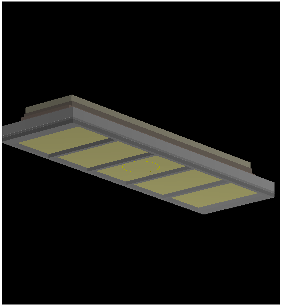
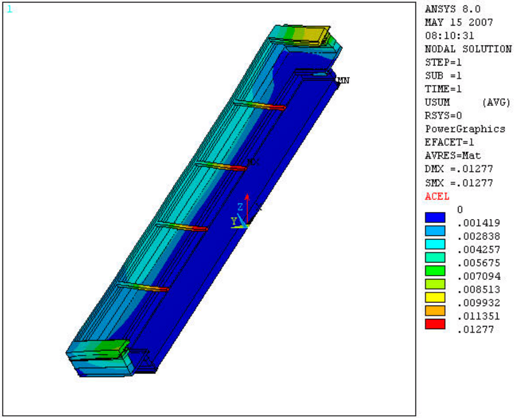


$\Rightarrow$



Radiator	15 mm thick Liquid Freon (C_6F_{14}, n=1.28)
Proximity Gap	100$\rightarrow$ **175** mm, filled with Methane at STP
Photon converter	300 nm CsI film coated on Pad Planes
Position Detector	3$\rightarrow$ **5** $\times$ pad planes = 1940 $\times$ 403$\rightarrow$ **2015 $\times$ 646** mm^2
	Multi Wire/Pad Proportional Chamber, HV= 1050 $\div$ 1100 V
Pad Plane	403.2 $\times$ 640 mm^2 (single pad: 8.4 $\times$ 8 mm^2)
FE Electronics	11520$\rightarrow$ **19200** analog chs, multiplexed S&H

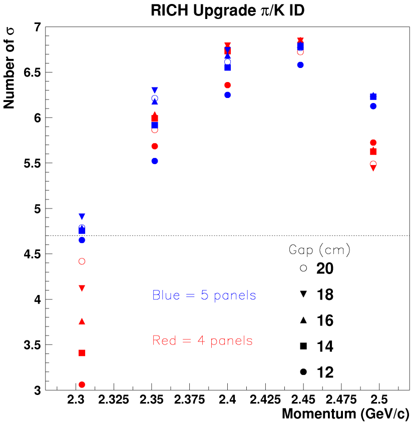
RICH Upgrade: FEM Analysis

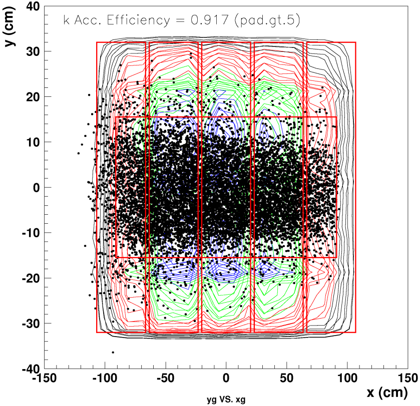


Max distorsions < 0.02 mm

RICH Upgrade: Simulated performance

Montecarlo tuned with real data on original RICH





Expected rejection $< 1 : 1000$ π:K in whole acceptance

Summary and conclusion

- Original RICH operated succesfully in Hypernuclear (and Pentaquark) experiment in Hall A at JLab, providing π:K rejection better than 1:1000 at 2.0 GeV/c
- New - high rank - experiment on transverse spin structure of the nucleon demands for similar rejection at 2.4 GeV/c
- Two upgrade options (providing similar performance) have been considered:
  1. new liquid freon (C_5F_{12}, lower refractive index)
  2. extend the photon detector area
- The latter option has been selected due mainly to
  - higher cost of the C_5F_{12} freon (and uncertainty in transmittance)
  - time schedule of the experiment does not allow significant R&D
- 1π in more than 1000 identified K predicted by Montecarlo tuned on real data (at $\sim$ 90% efficiency)

- Upgrade is in progress: new detector expected for the end of 2007
- New RICH will operate in transversity experiment in summer 2008

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