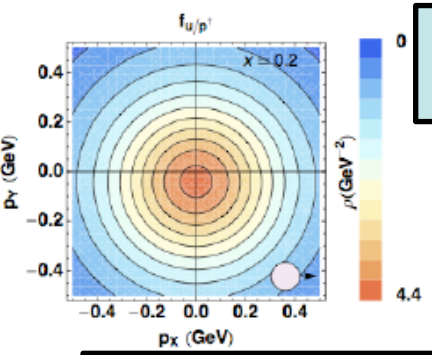
Struttura del nucleone: TMD
Il RICH e HD-Ice per CLAS12

Marco Mirazita (LNF)

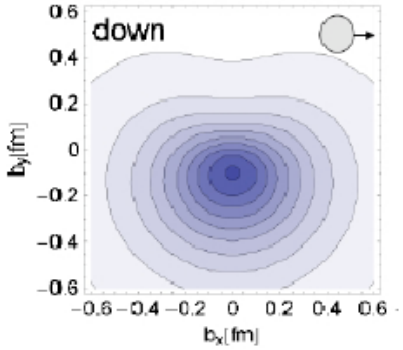
Parton distribution functions



$W_p^q\left(x, \vec{k}_T, \vec{r}\right)$ **Wigner "mother" functions**

$\int d\vec{r}$

$\int d\vec{k}_T + FT$



$f_1\left(x, \vec{k}_T\right)$ **TMD PDFs**

Semi-inclusive measurements
Momentum transfer to quarks
Momentum distributions

$H_p^q\left(x, \xi, t\right)$ **GPDs**

Exclusive measurements
Momentum transfer to target
Spatial distributions

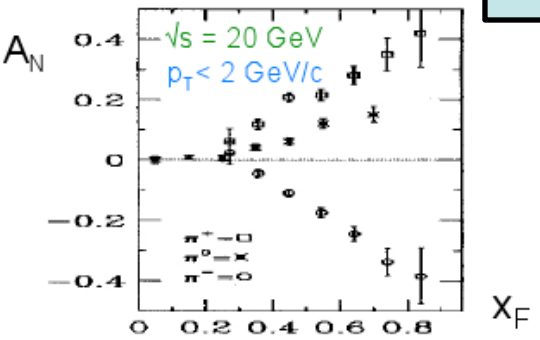
may explain SSA

$\int d\vec{k}_T$

$t = \xi = 0$

may solve proton spin puzzle

$f_1(x)$ **collinear PDFs**



$$J_q = \frac{1}{2}\Delta\Sigma + L_q = \lim_{t\to 0}\int_{-1}^{1} dx\; x\left[H(x,\xi,t) + E(x,\xi,t)\right]$$

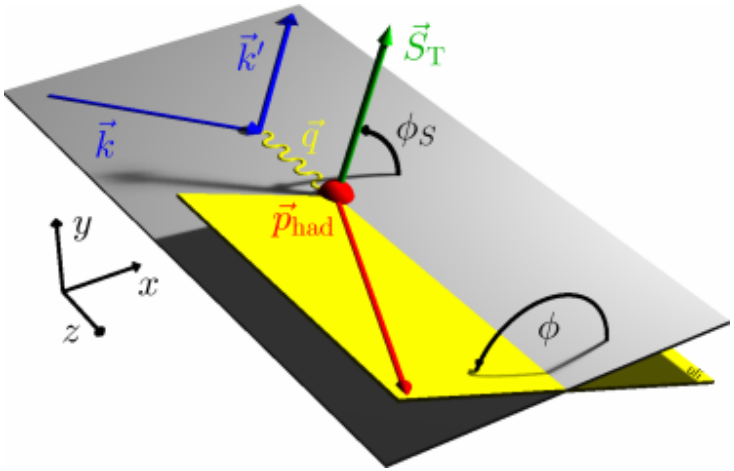
Angular momentum sum rule

TMDs at leading order

quark polarisation

nucleon polarisation

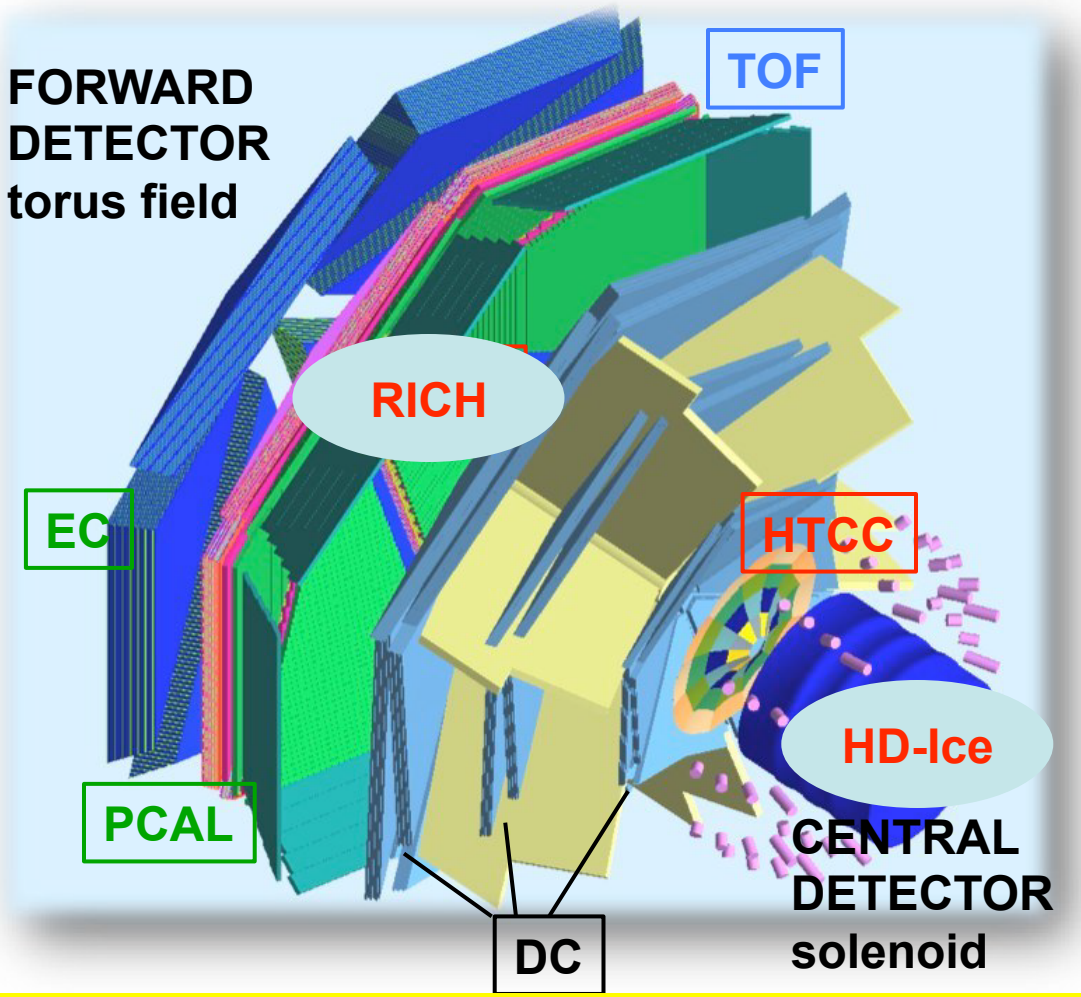
N/q	U	L	T
U	f_1 Number Density		$h_1^\perp$ Boer-Mulders
L		g_1 Helicity	$h_{1L}^\perp$ Worm-gear
T	$f_{1T}^\perp$ Sivers	$g_{1T}^\perp$ Worm-gear	h_1 Transversity; $h_{1T}^\perp$ Pretzelosity



TMDs can be accessed in Semi-Inclusive DIS reactions by looking at specific azimuthal modulations in ϕ and ϕ_S of the cross section with polarized beam and target

$$\sigma = \sigma_{UU} + S_T\, \sigma_{UT}\, sin(\phi - \phi_S) + \lambda\, \sigma_{UL}\, sin\phi + ...$$

CLAS12 in Hall B



- Luminosity up to 10^{35} cm^{-1} s^{-1}
- Highly polarized electron beam
- H and D polarized targets
- Broad kinematic coverage, from target to current fragmentation

Required upgrades for nucleon 3D investigation:

RICH: Hadron ID from 3 to 8 GeV/c for flavor separation

HD-Ice: new concept of transversely polarized target

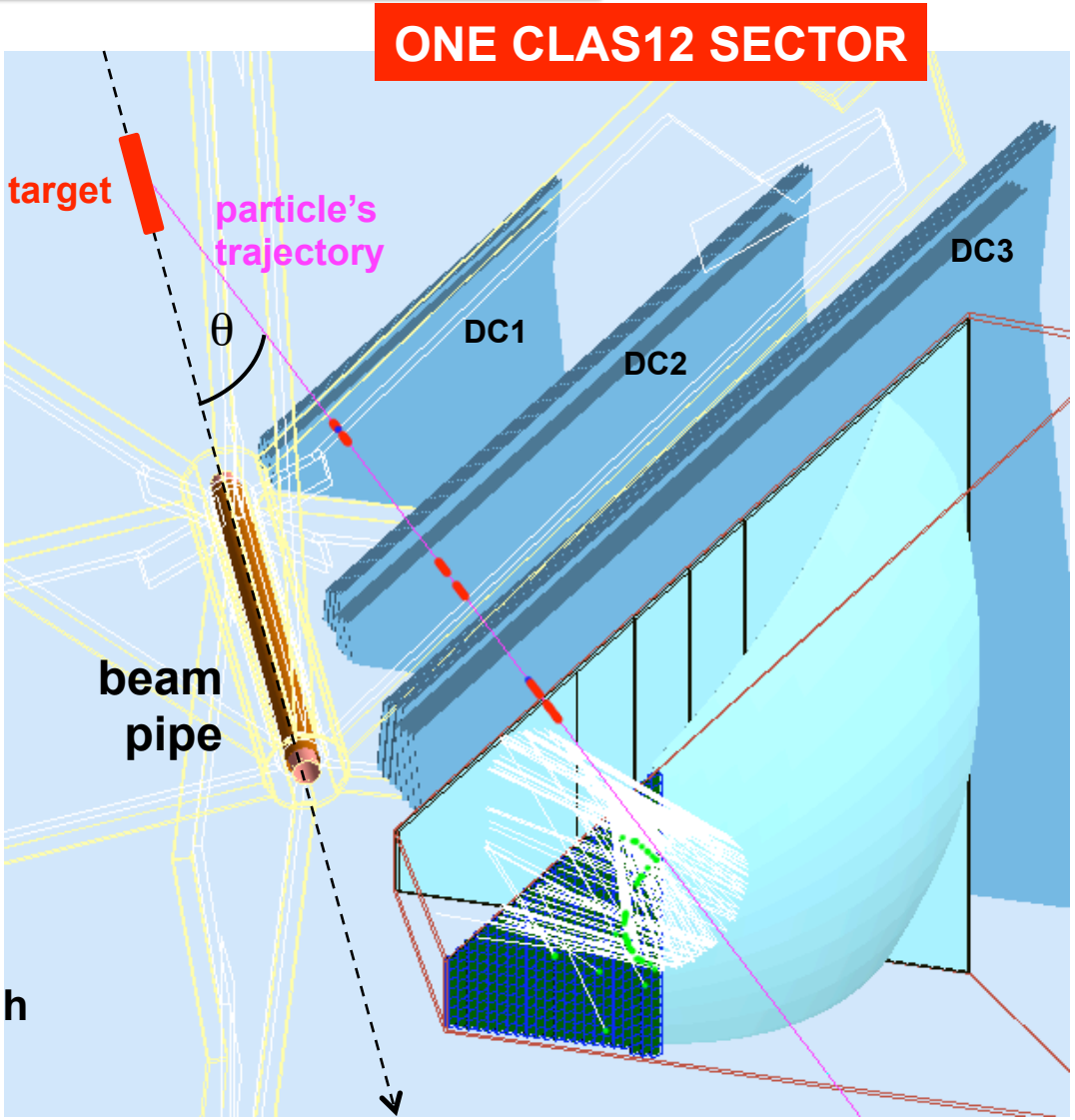
PAC30 report (2006):
Measuring kaon asymmetries is likely to be as important as pions…… The present capabilities of the CLAS12 design are weak in this respect and should be strengthened

Layout of the RICH

Requirements:
- π/k/p separation in the 3-8 GeV/c range
- π rejection >500

Constraints:
- the detector must fit in 1m
- low material budget
- large area for the photodetectors (several m^2)
- increasing azimuthal angle → decreasing momentum

Solutions:
- mirrors to focalize the light in small area
- variable aerogel thickness from 2 to 6/8 cm



Different pattern:
- Cerenkov photons from small angle, high momentum particles directly detected
- photons from large angle and lower momentum particles are reflected toward the photodetectors and pass twice through the aerogel

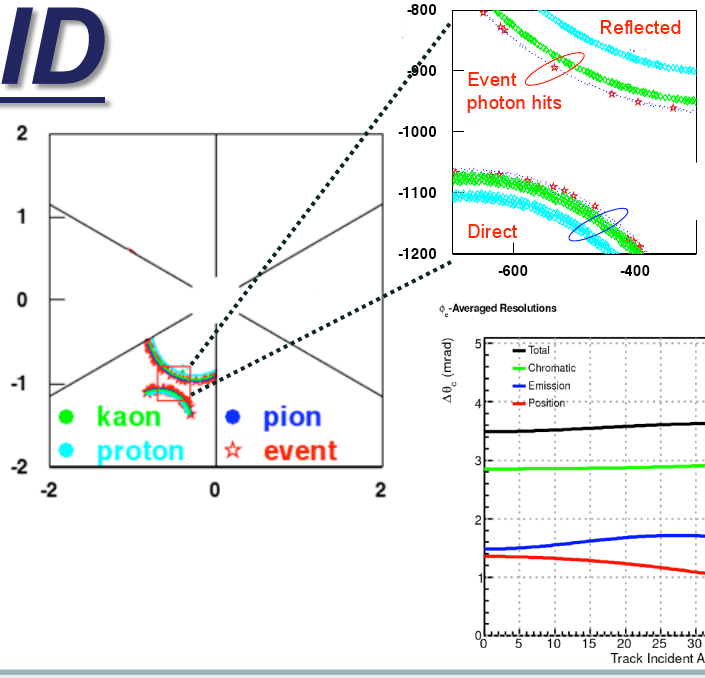
Particle ID

- Images are no more rings
  - need high level reconstruction algorithms
  - study backgrounds (Rayleigh)
- "Ring" reconstruction
  - single photon resolution

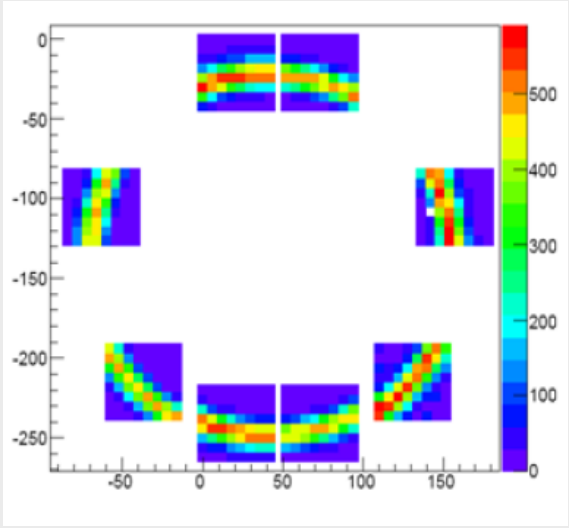
$$\sigma_{1\gamma}^2 = \sigma_{pos}^2 + \sigma_{chr}^2 + \sigma_{emi}^2$$

  - number of photons

$$\sigma_{ring}^2 \approx \frac{\sigma_{1\gamma}^2}{N_{pe}}$$



First preliminary test at CERN (summer 2011)



- 10 GeV/c pions
- 2cm aerogel, n=1.05
- H8500 MAPMTs

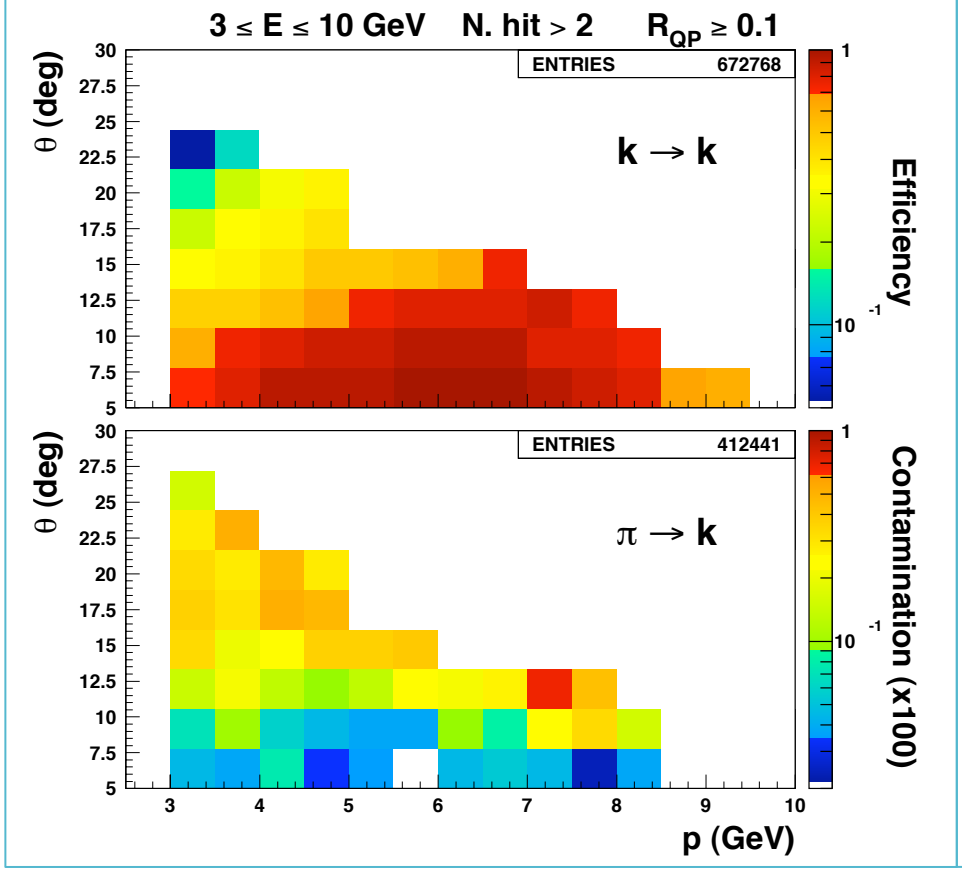
⇒ more than 10 p.e.

RICH simulations

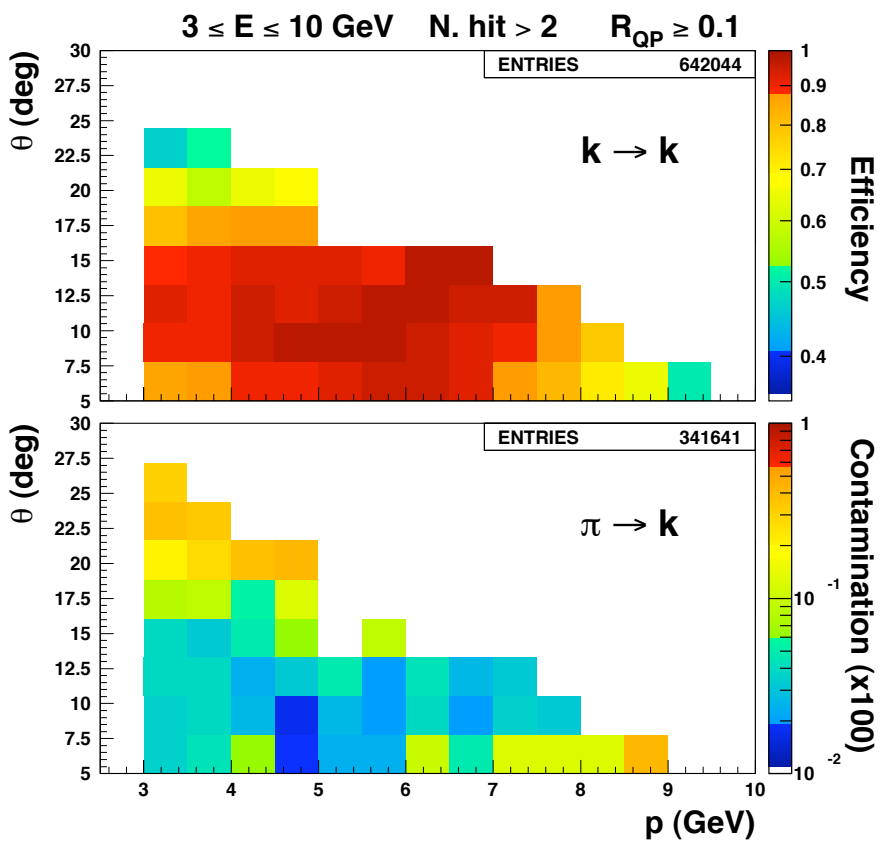
Full simulation of the RICH detector

tuned with lab. and beam tests data

positive particles

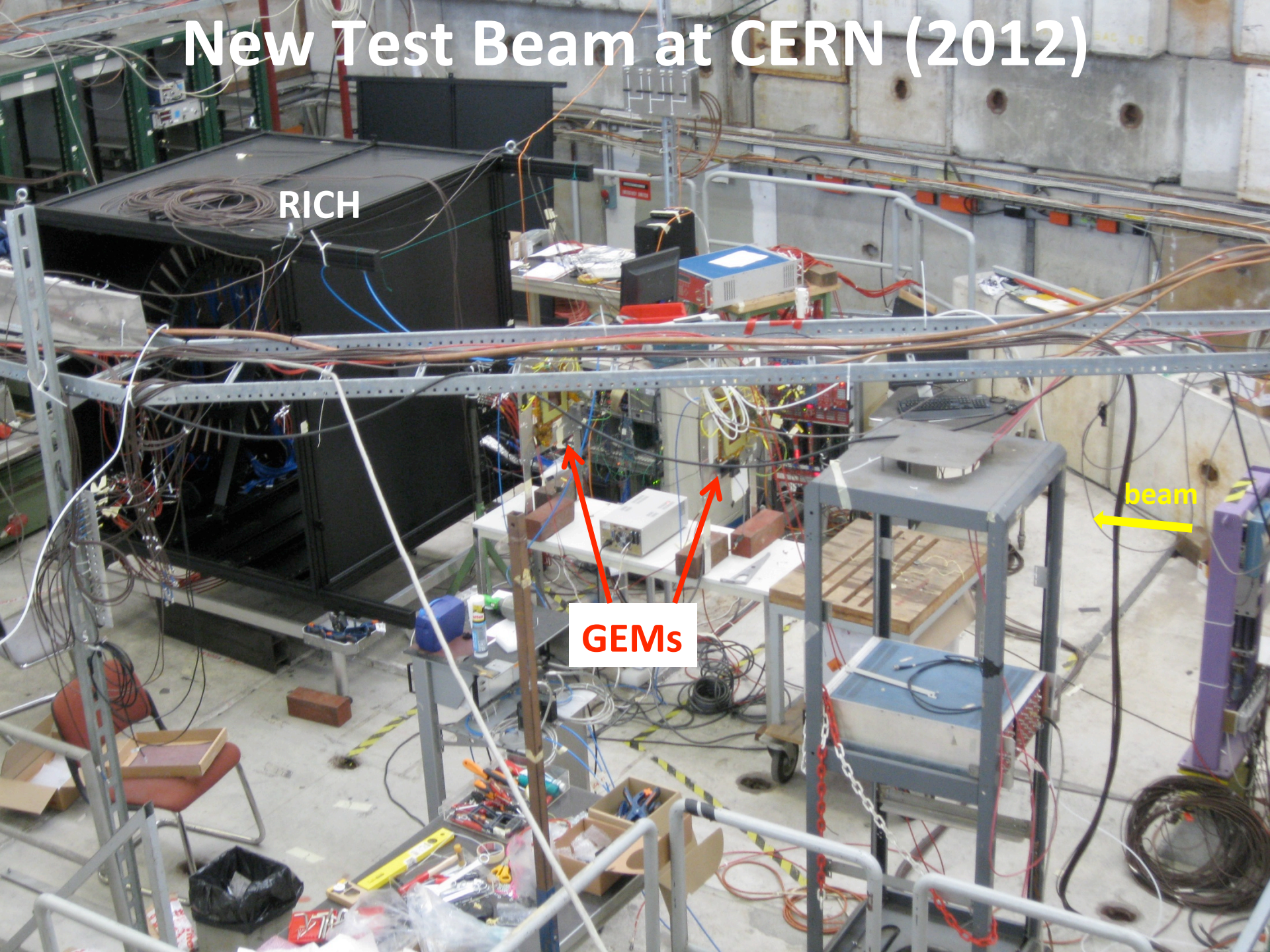


negative particles

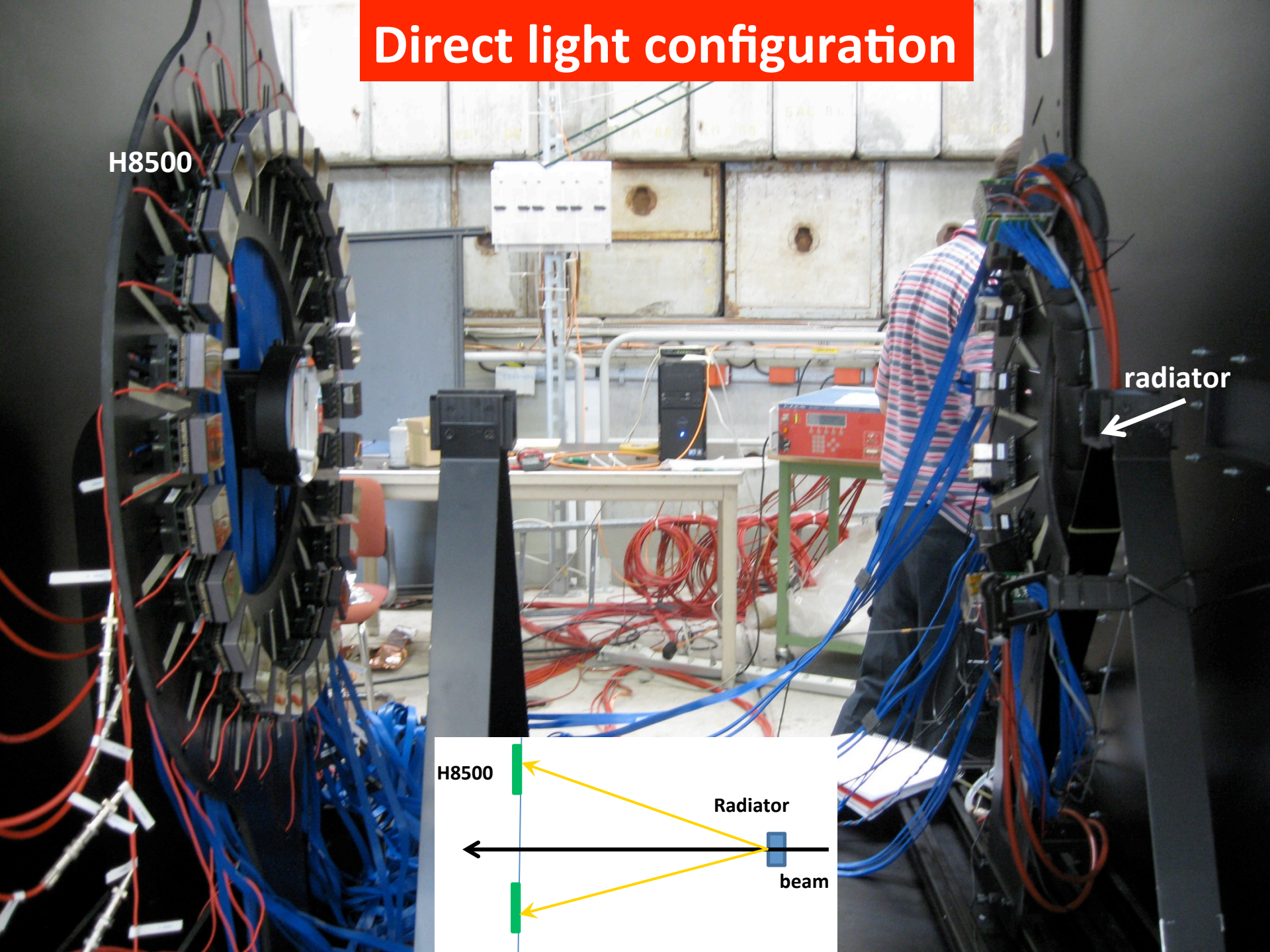


- High efficiency in most of the kinematic plane
- Low contamination

New Test Beam at CERN (2012)



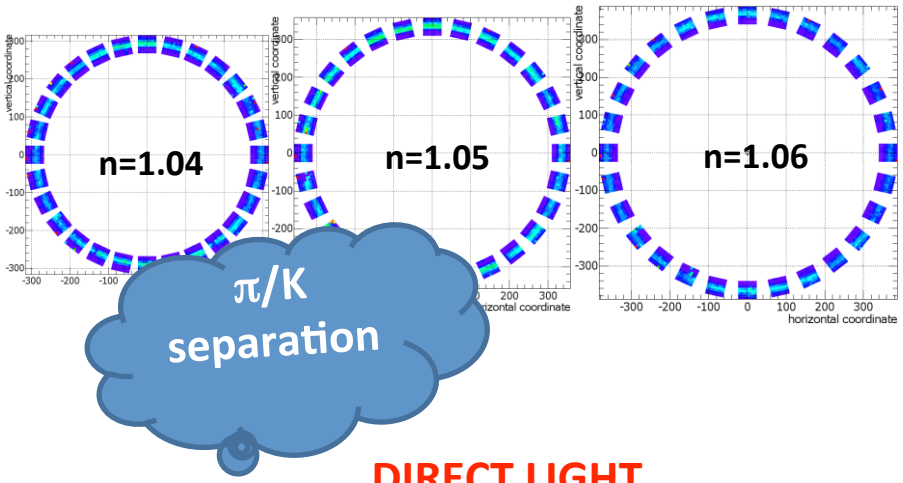
Direct light configuration



Some “on line” analysis

DIRECT LIGHT

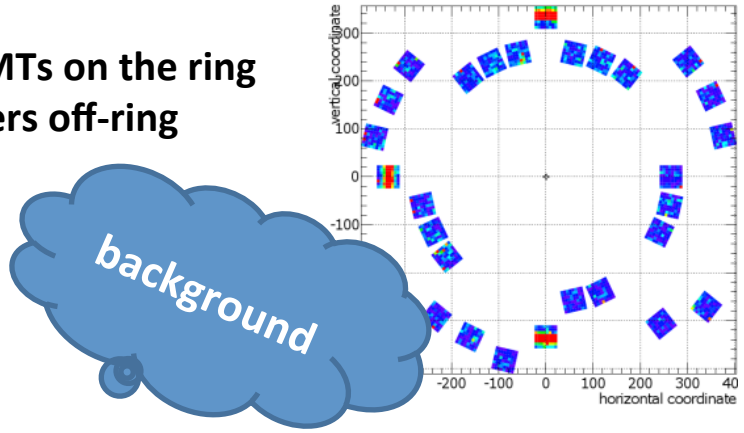
different refractive index and thickness



DIRECT LIGHT

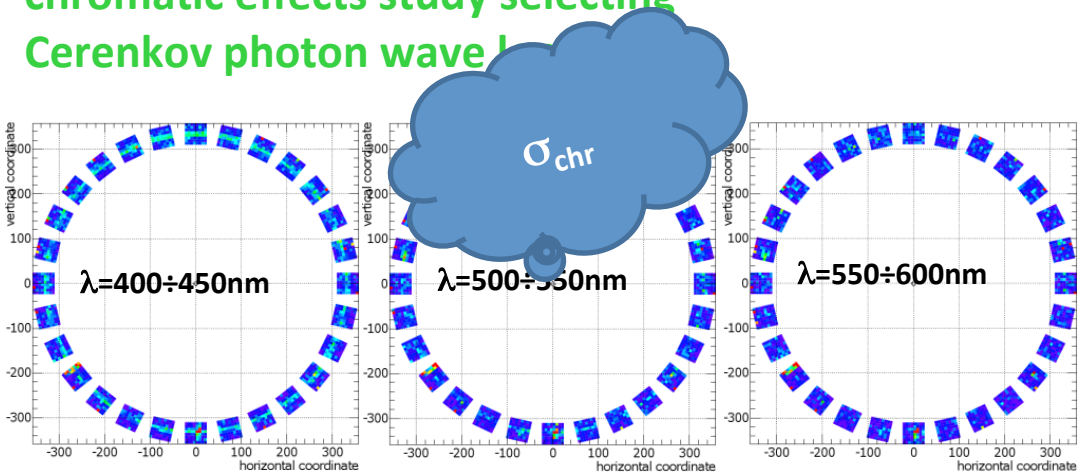
Rayleigh scattering study

3 PMTs on the ring
others off-ring



DIRECT LIGHT

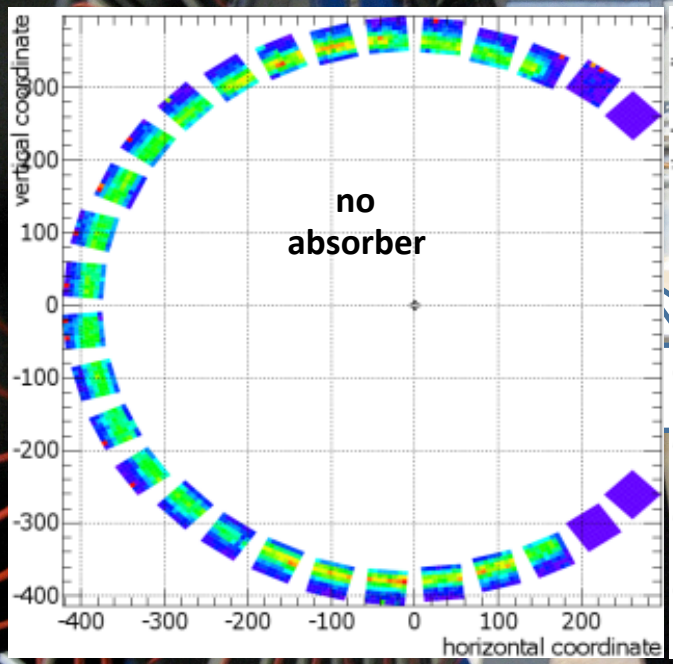
chromatic effects study selecting
Cerenkov photon wave l

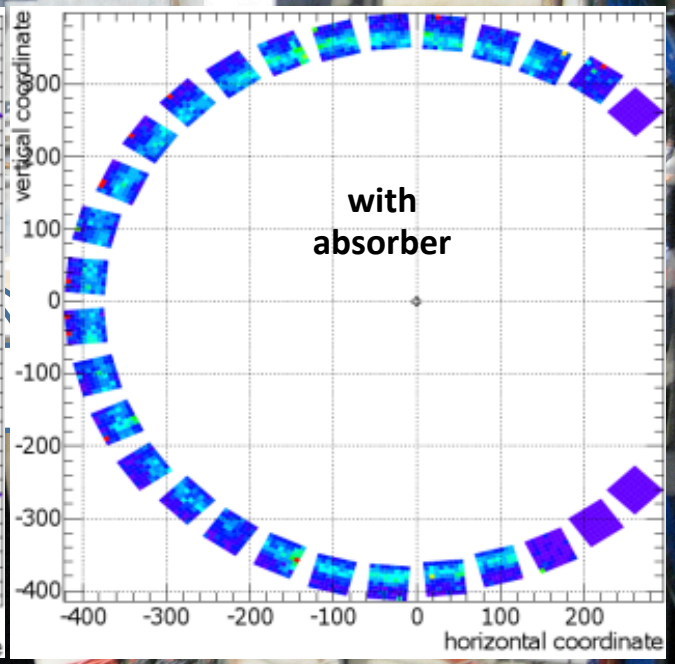


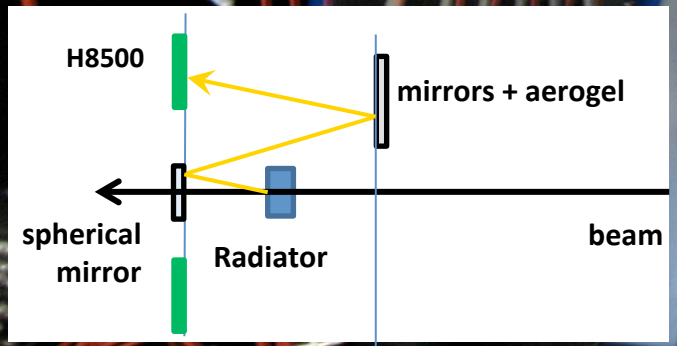
Reflected light configuration

planar mirrors
aerogel absorber

H8500







The RICH project

INFN groups:

- **Bari/Lecce, Ferrara, Frascati, Genova, ISS/Roma1**

Many International Institutions:

- **JLab (USA)**
- **Argonne National Laboratory (USA)**
- **Christopher Newport University (USA)**
- **University of Glasgow (UK)**
- **Universidad Tecnica Federico Santa Maria (Chile)**

Timeline:

- **middle 2015: installation of one sector in CLAS12**
- **second RICH sector for transverse physics (2018?)**

JLab milestones for the next 5 years

- **The physics using the RICH detector is strongly supported by Jefferson Lab. Projected science highlights for the next 5 years submitted to NSAC/DOE:**

A first generation of exclusive and semi-inclusive deep inelastic lepton scattering experiments worldwide promises a novel multi-dimensional view of nucleon structure in the valence quark region in terms of spatial and momentum tomography. However, virtually nothing is known concerning these quantities when **strange quarks** come into play. **Experiments will provide for the first time precision measurements adding strangeness information for deep virtual kaon production**. Further experiments will provide (transverse) momentum tomography for charged-kaon production, precisely measuring the strange quark momentum distribution for which recent HERMES data uncovered a surprising shape, and precisely constraining the spin/flavor structure of the light quark sea.

NSAC Subcommittee Meeting - September 7-9, 2012

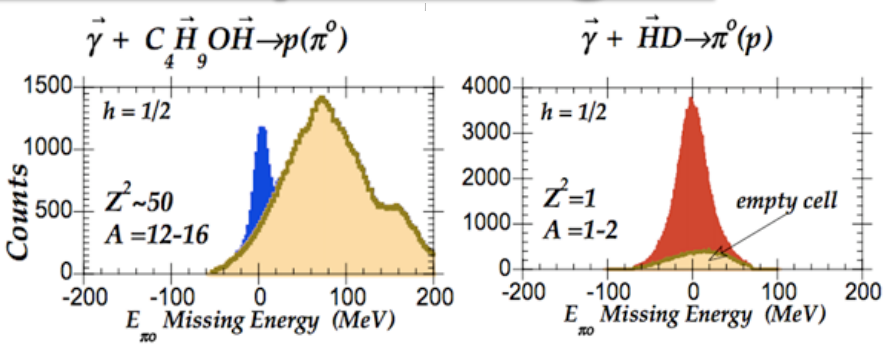
- **Support for the first RICH sector is included in the Lab's budget planning starting in FY13 and funds projected in FY14 and FY15**

	FY13	FY14	FY15
RICH Hall B	200K$	500K$	500K$

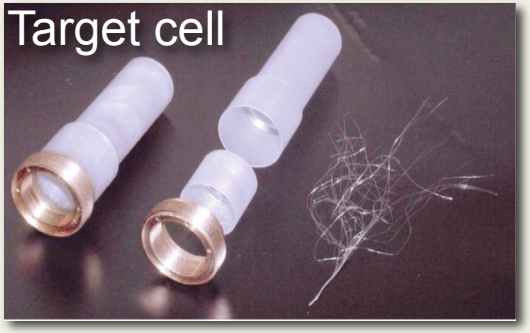
HD-Ice: polarized frozen spin target

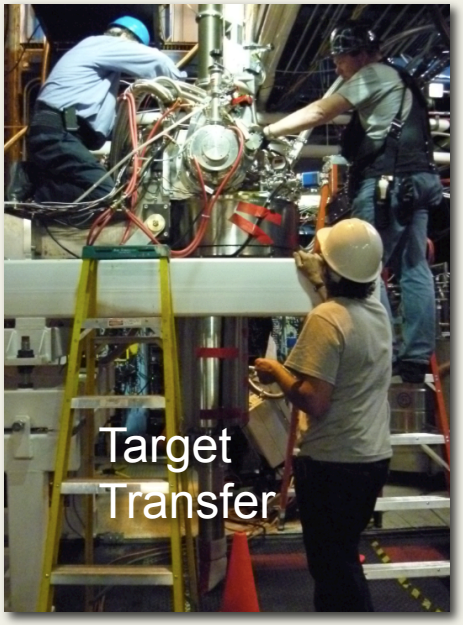
Advantages:
- large acceptance
- minimize nuclear background
- high polarization, up to 75% H and 40% D

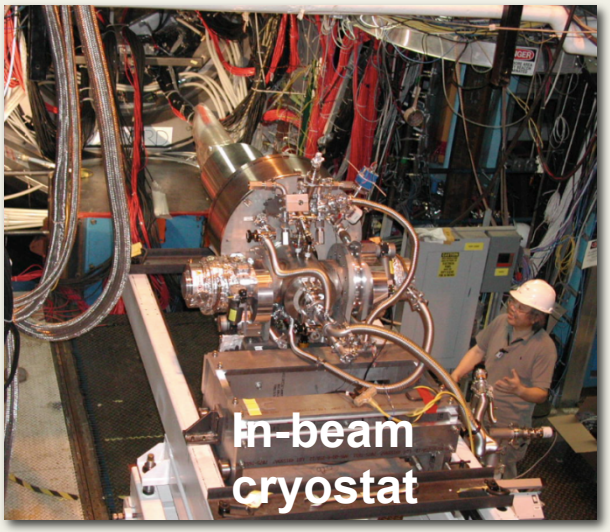
Disadvantages:
- long polarizing time (months)
- sensitive to local heating
- lower max luminosity: ~5 10^{33} cm^{-2} s^{-1}



Production process:
- dilution of HD gas
- polarization of the HD at 23mK and 15 T
- transfer to IBC at 2.8K and 0.5T

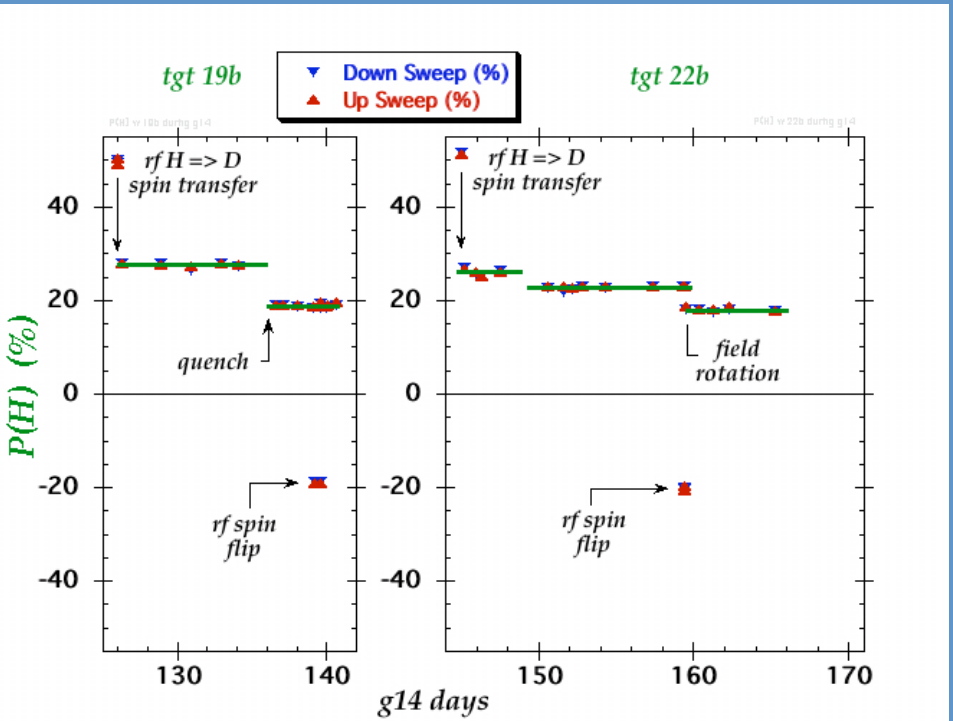






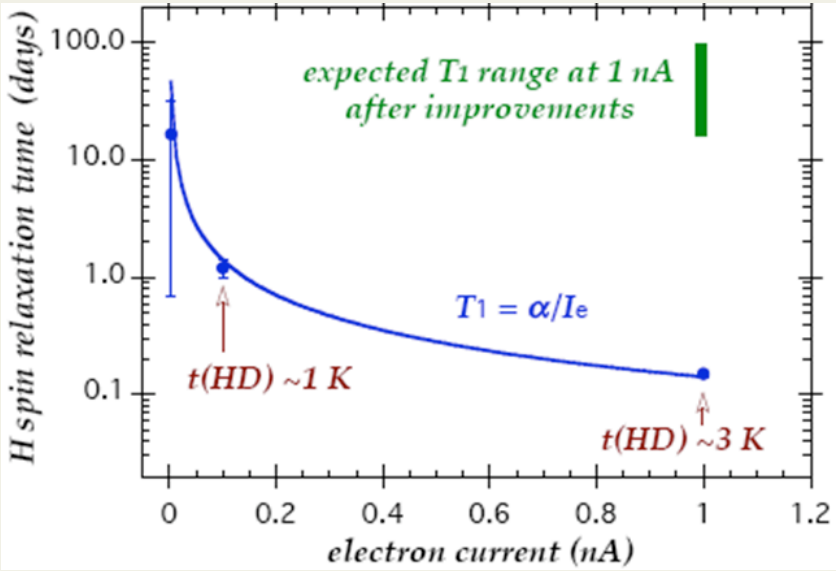
6 GeV runs with HD-Ice

Photon runs from Nov. 2011 to May 2012
- photon flux ~10^8 γ/s
- relaxation time T1 ~ years



Electron runs Feb. and Mar. 2012
- Short relaxation time during beam exposure

⇒ heat removal needs improvement
- faster raster
- new cell geometry



Commissioning run foreseen with early Beam, before CLAS12 operations

Conclusion

TMD measurements are one of the main items of the JLab physics program at 12 GeV.

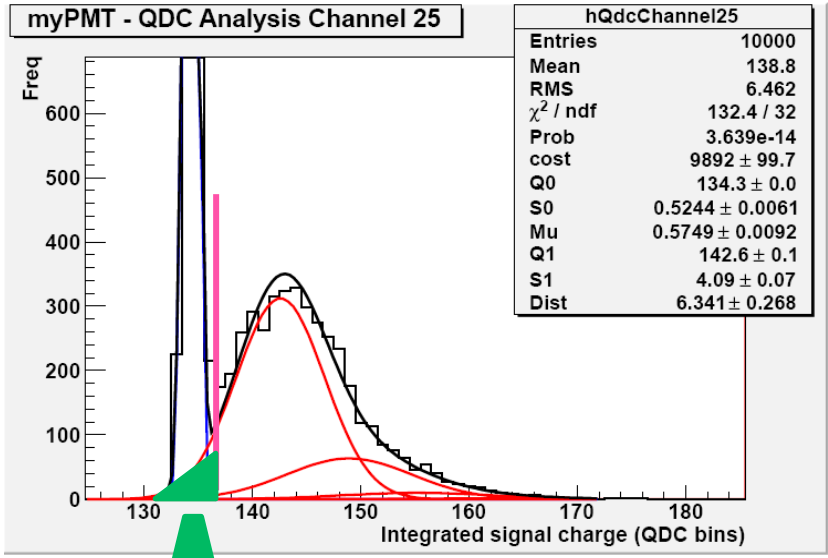
Large activity from INFN groups to provide CLAS12 with the necessary upgrades:

- **RICH detector**
  - **simulations**
  - **test of photodetectors: Multi-Anode PMT and SiPM**
  - **characterization and development of aerogel**
  - **Electronics: MAROC2 and MAROC3**
  - **Design and construction of a detecor prototype**
  - **Test beams**

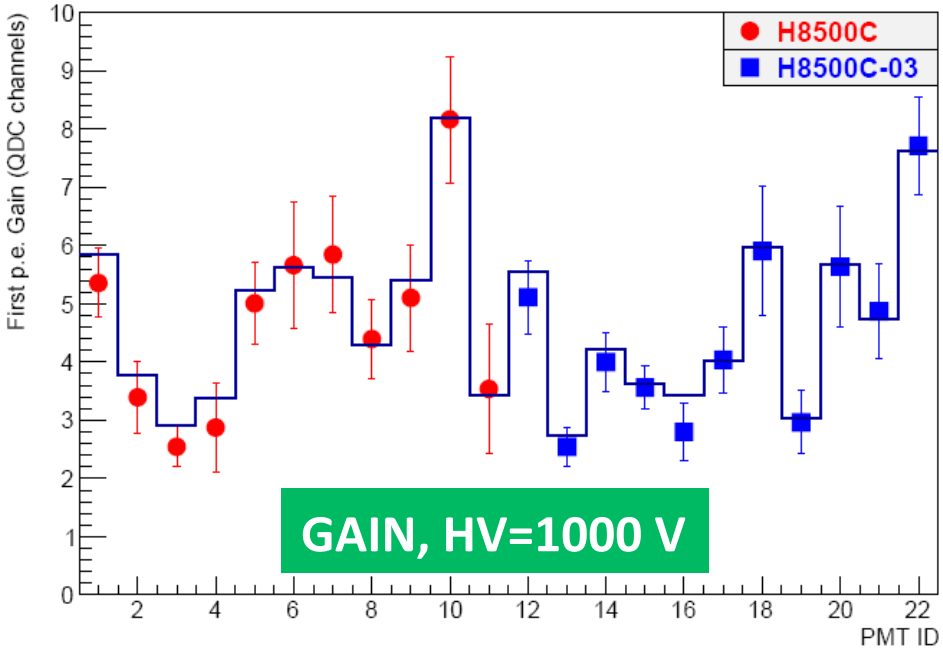
- **HD-Ice target**
  - **characterization of the HD gas and relative concentration of H^2 and D^2**
  - **contribution to the realization of cryostat for the gas concentration and of the In-Beam Cryostat**
  - **NMR measurements**
  - **design of the transverse holding magnet operating within the CD solenoid**

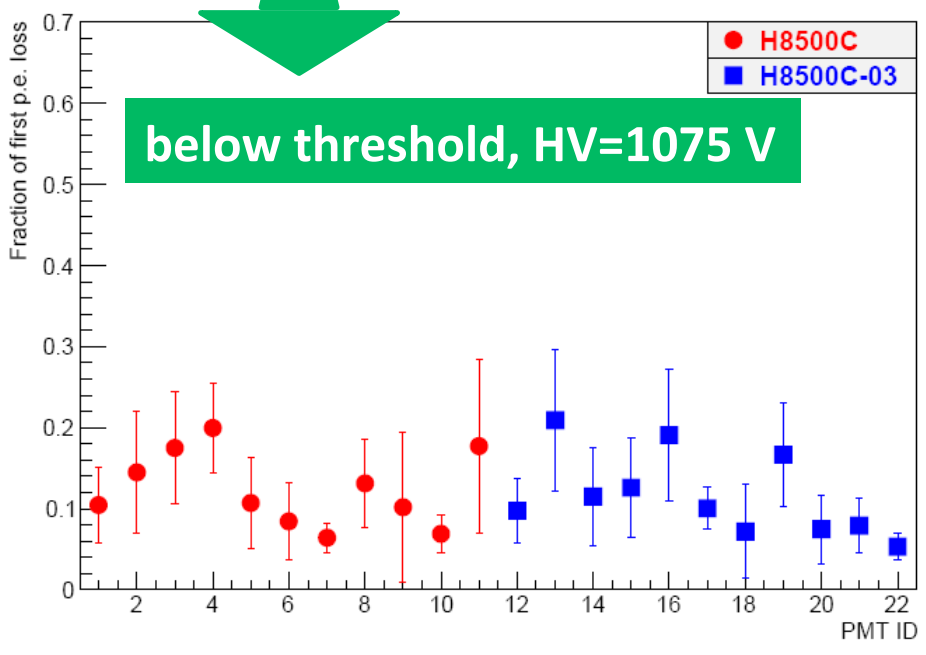
Laser test of H8500 MAPMTs

- Laser intensity adjusted via the remote control and using neutral density filters
- The laser head remotely moved to scan the PMT surface
- Conventional electronics for data acquisition (CAEN V792)



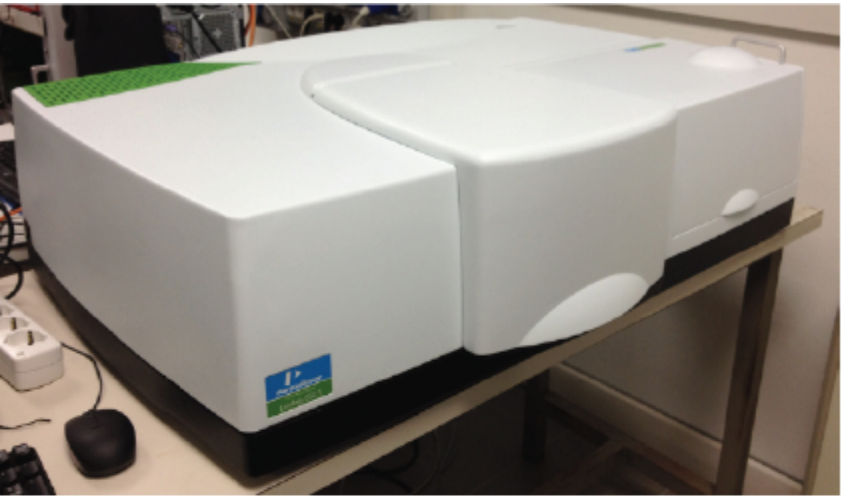
H8500 are good single photoelectron detectors

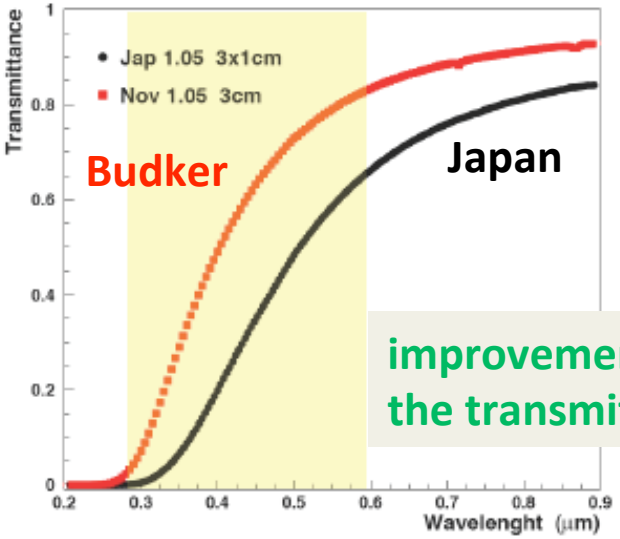




Aerogel characterization

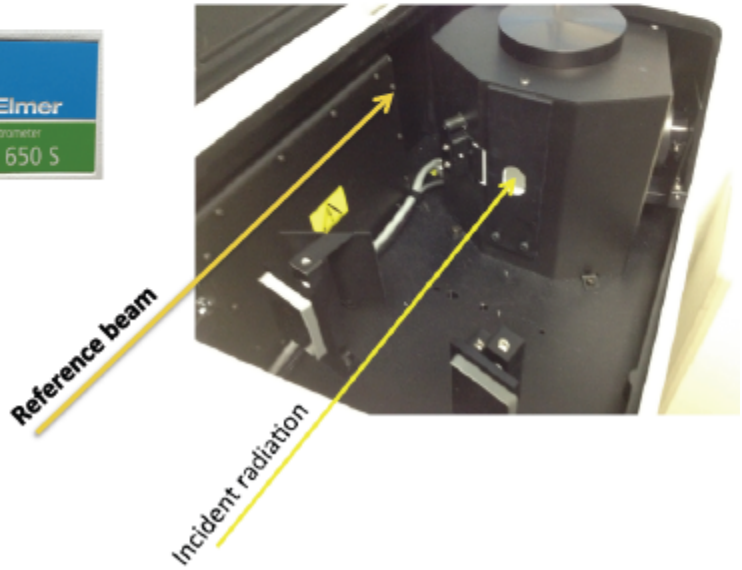
Collaboration with Budker Institute for high transmission aerogel production, with different thickness and refractive index

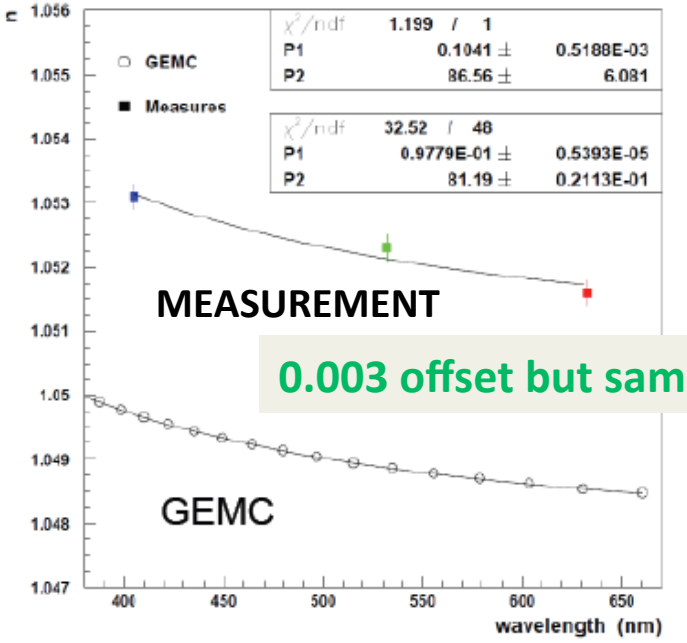




improvement in the transmittance

PerkinElmer
UV/VIS Spectrometer
Lambda 650 S

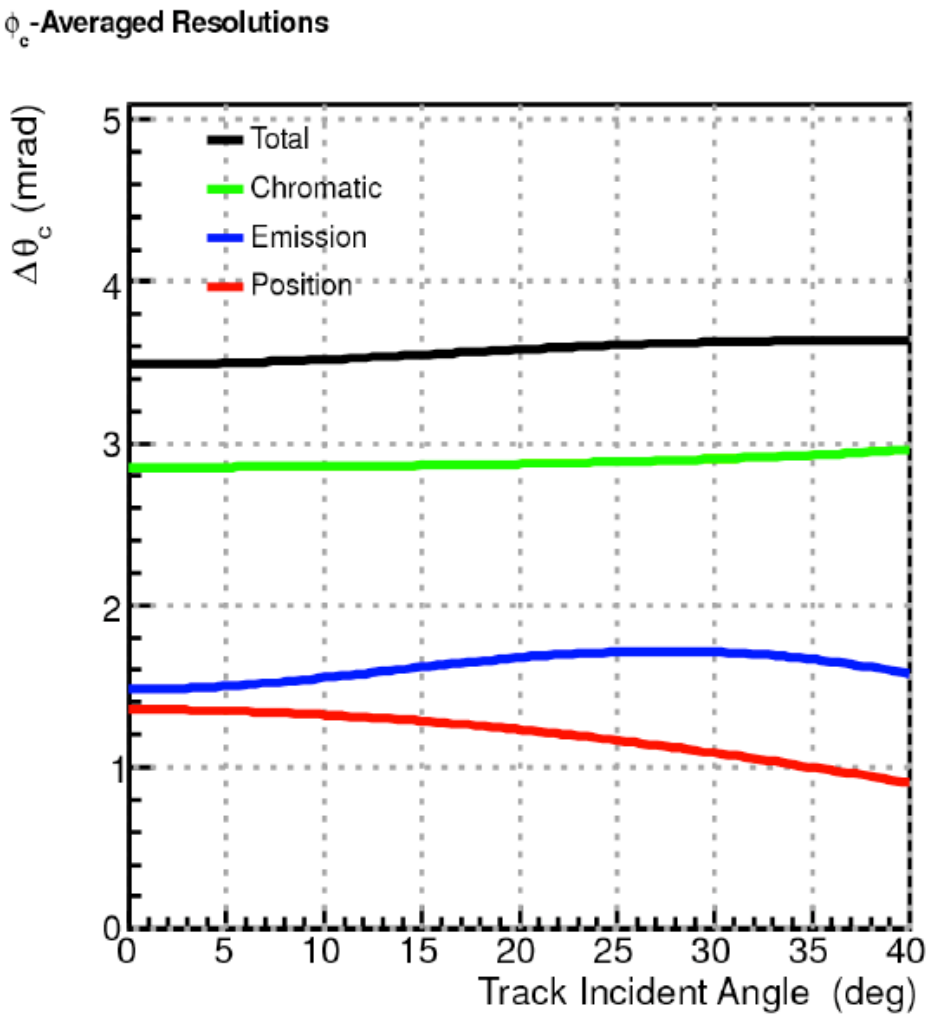




0.003 offset but same trend

Single Photon Resolution

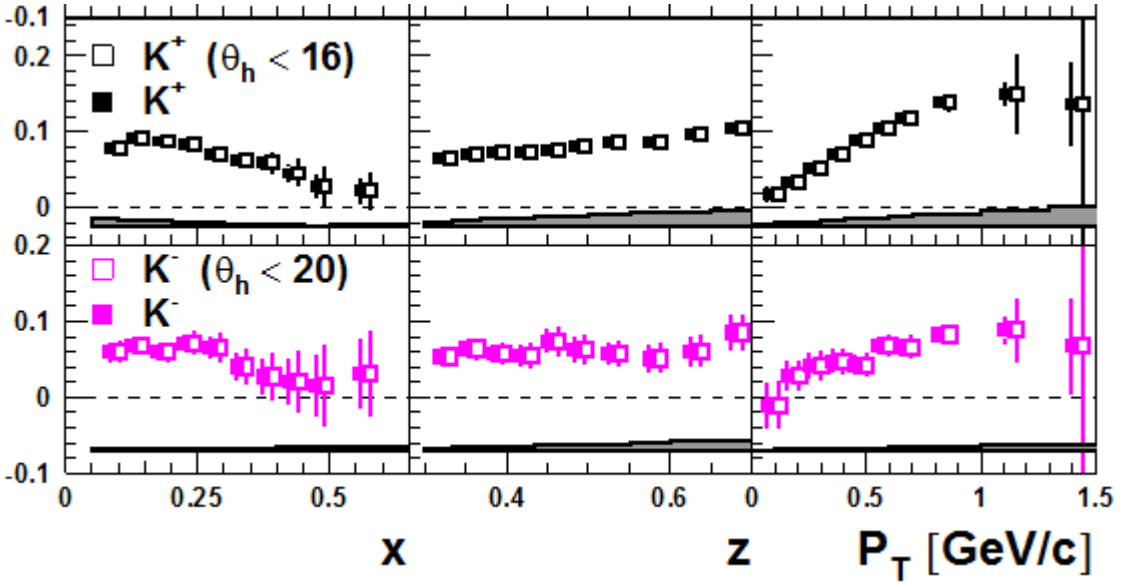
- **Calculation from Monte Carlo**
- **Simulation tested with experimental data in different configuration**



Index of Refraction = 1.05
Radiator Thickness = 20.0 mm
Gap Length = 105.0 cm
Pixel Size = 5.8 mm
σ_n = 8.7e-04

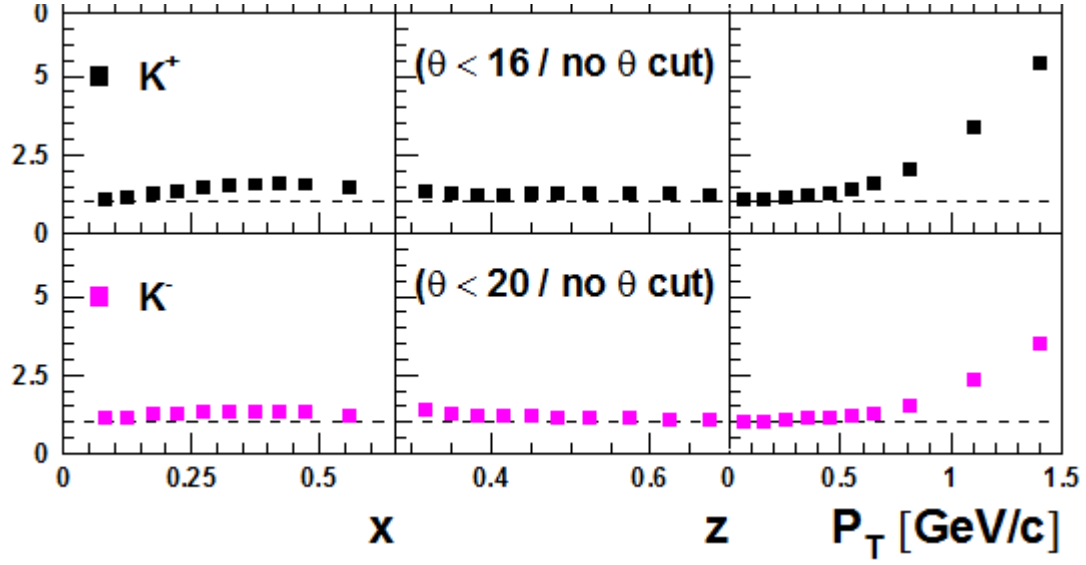
A_{UT} measurement with RICH

A_{UT}



Empty symbols: direct only
Full symbols: direct+reflected

Relative error increase



Kaon to pion production rates in CLAS12