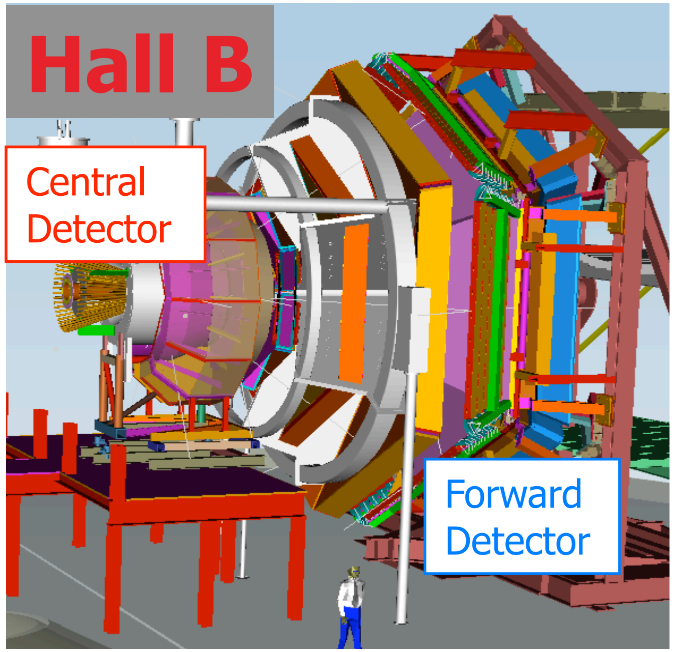
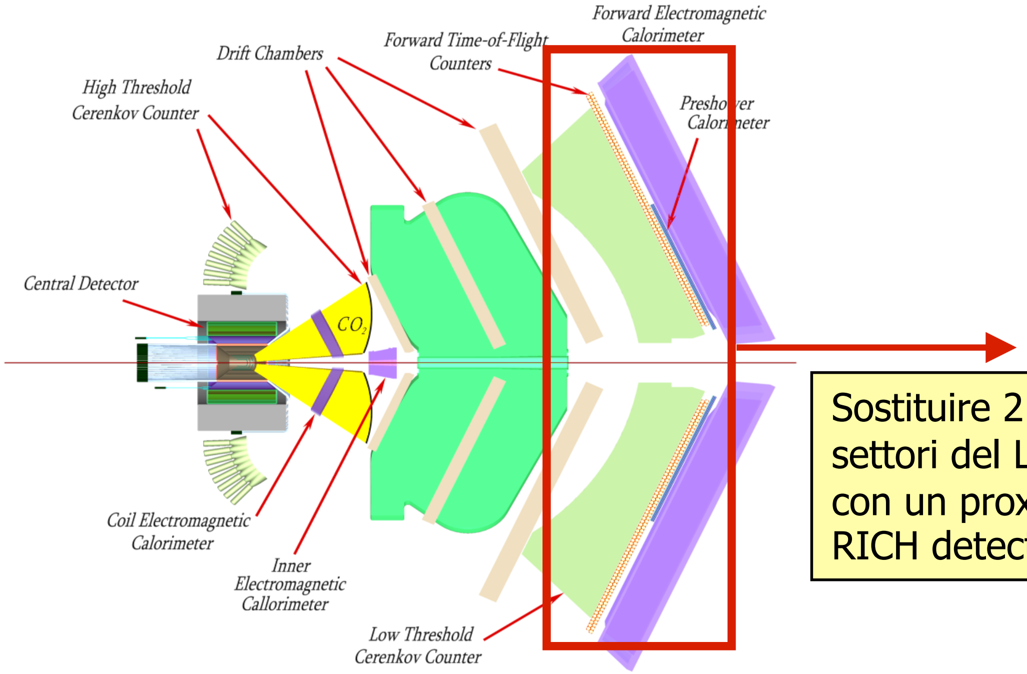
RICH simulation for CLAS12

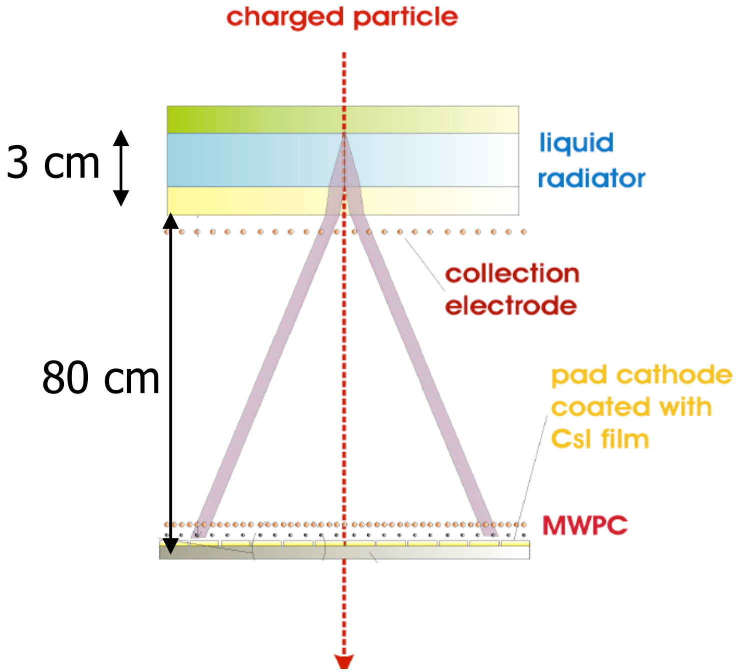


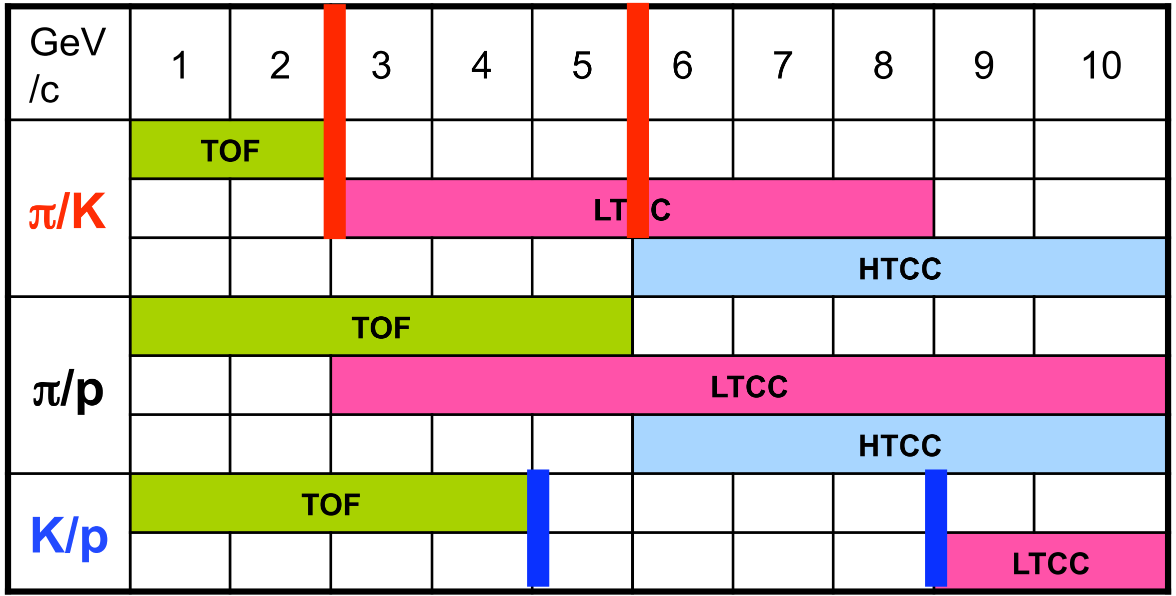
Contalbrigo Marco
INFN Ferrara
Luciano Pappalardo
INFN Ferrara

RICH detector



Sostituire 2 settori del LTCC con un proximity RICH detector





<table>
<tr><th>GeV /c</th><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th><th>8</th><th>9</th><th>10</th></tr>
<tr><td rowspan="3">π/K</td><td colspan="2">TOF</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td colspan="6">LT C</td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td colspan="5">HTCC</td></tr>
<tr><td rowspan="3">π/p</td><td colspan="5">TOF</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td colspan="8">LTCC</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td colspan="5">HTCC</td></tr>
<tr><td rowspan="2">K/p</td><td colspan="4">TOF</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="2">LTCC</td></tr>
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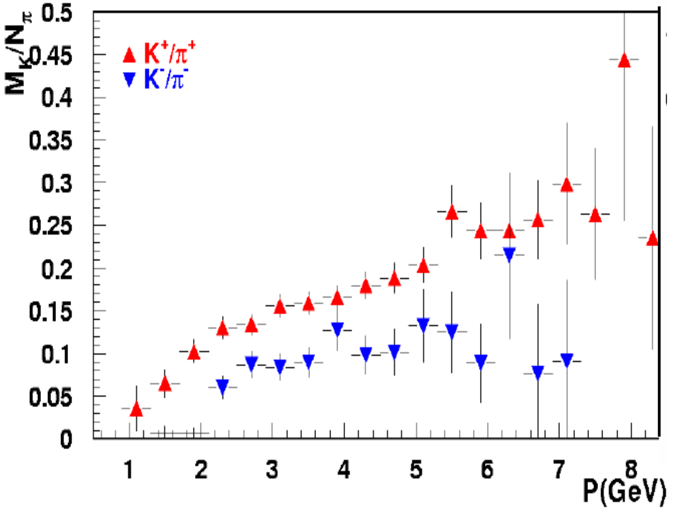
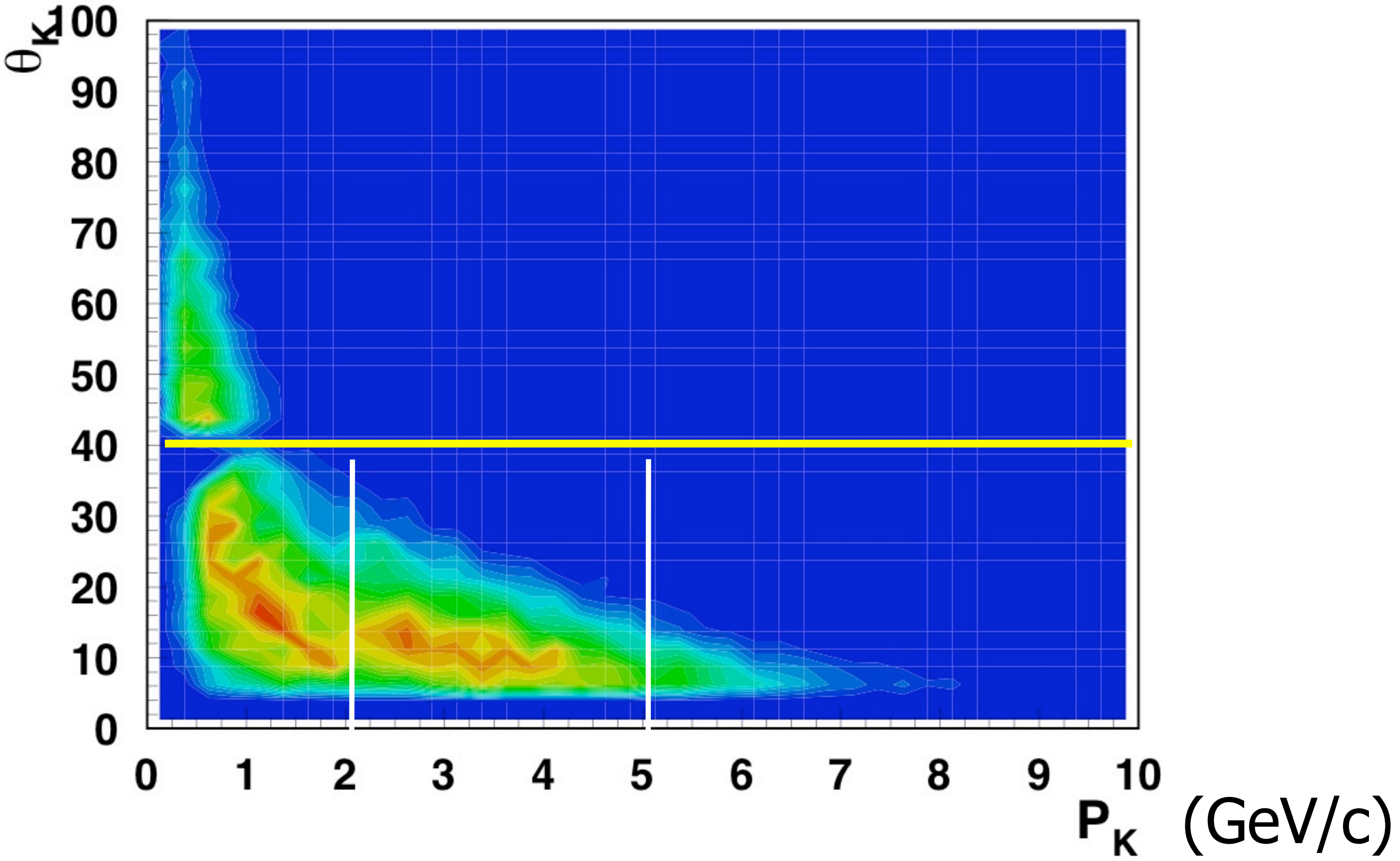


- rapporto K/π ~ 0.1-0.15

Simulation with realistic phase space

To detemine the best photon detector size, π,K,p have been generated at the LTCC-RICH entrance window according with a realistic phase space distribution of reconstructed momenta and angles.

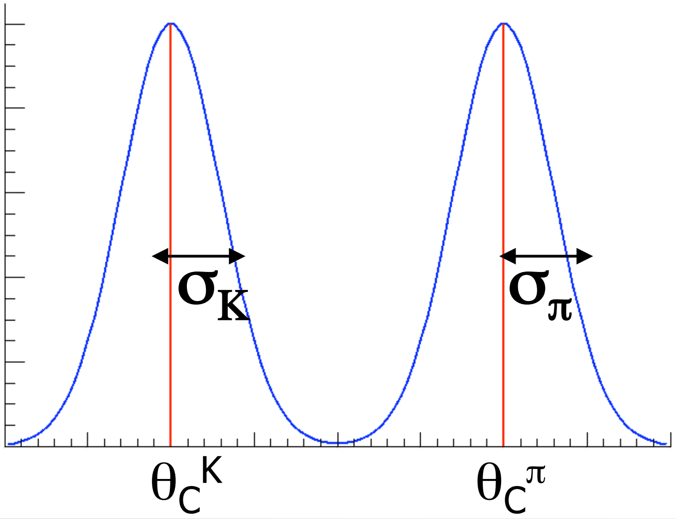


Monte Carlo studies: framework

- Old GEANT3/Fortran/PAW based MonteCarlo framework
  the same used the for the development of the Hall A Proximity RICH but with **different geometry and size**!
- Charged particles phase space at the LTCC-RICH entrance window from CLAS simualtion, same distribution for π,k,p
- Use arcs as radiator and detector geometries (see next)
- Limitation on photon production (~3000)
  old memory constraint. This becomes relevant for radiator thickness > 2.5-3.0 cm

Main output parameter:
$\sigma_{k\pi}$= mean error on Cherenkov angle reconstruction of k and π

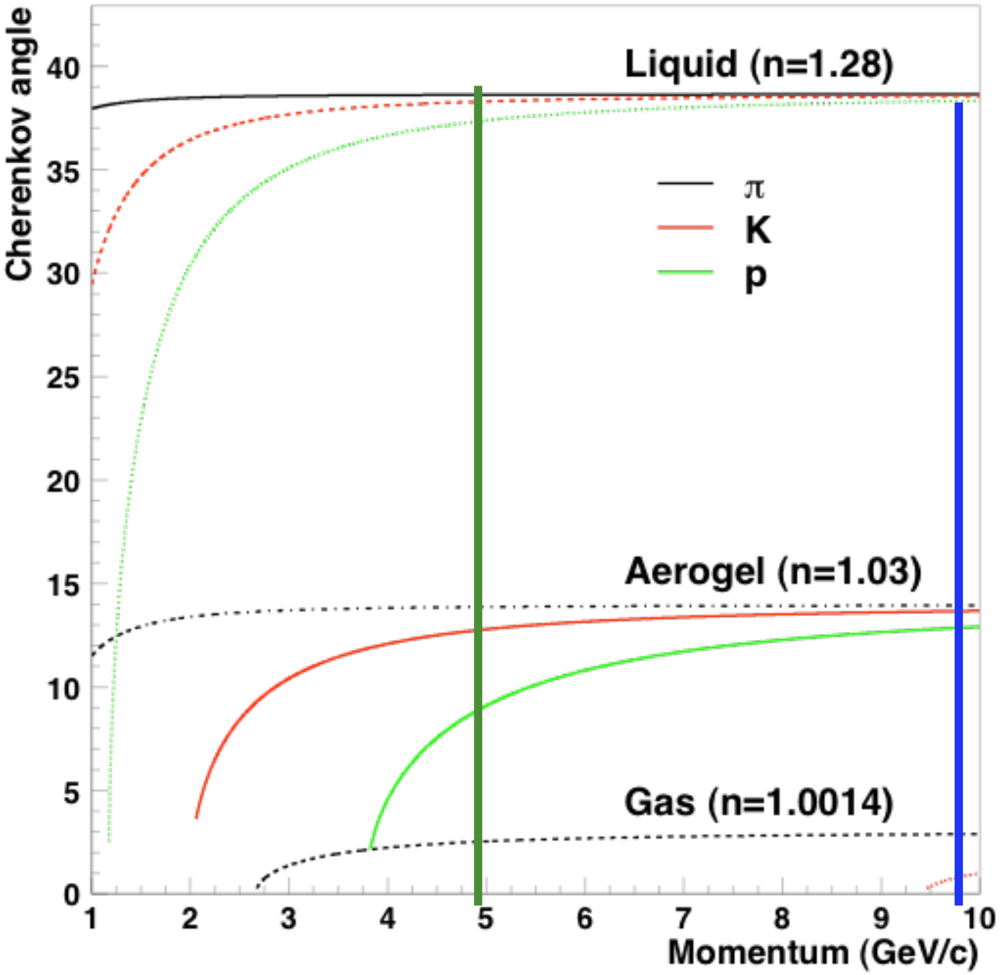
$$\sigma_{K\text{-}\pi} = (\sigma_K + \sigma_\pi)/2$$



Which RICH?

- **Liquid Radiator (Freon)**
  - –May cover up to 5 GeV/c
  - –Relatively inexpensive (proximity focusing RICH)

- **Aerogel + Gas Radiators**
  - –May cover up to 10 GeV/c
  - –Very expensive (cost Aerogel RICH ~ 5x Proximity Focusing RICH)



UV light

- Hall-A approach
- Multiwire chambers (with CSI) suitable as cheap photon detector of large area

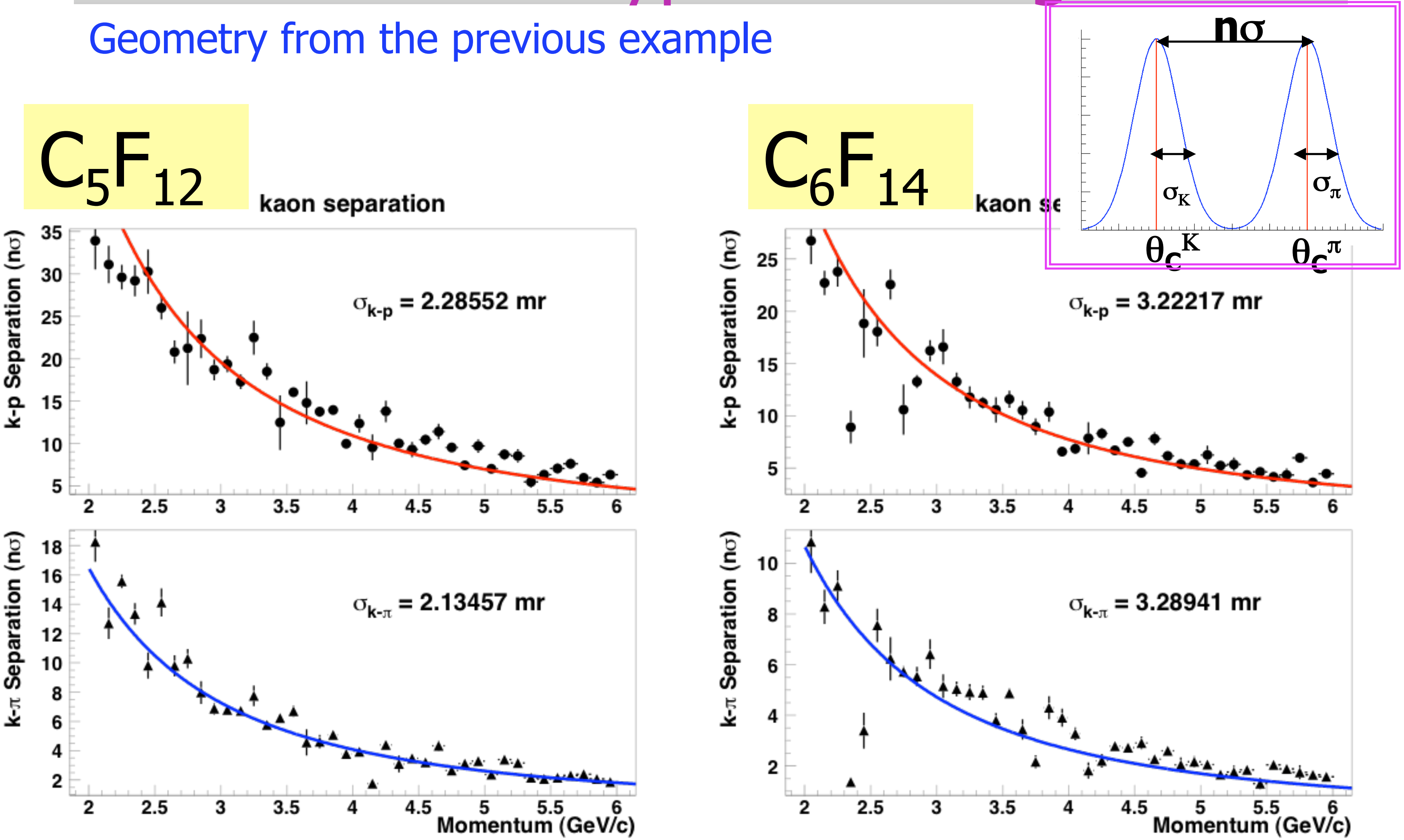
- C_6F_{14} has not enough discrimination power at large momenta
- C_5F_{12} is technologically challenging:

  liquid only below 29^o

  needs 0^o to keep same vapor pression of C_6F_{14}

Radiator Type for UV light

Geometry from the previous example



C_5F_{12}

C_6F_{14}

Points: MonteCarlo,
Curves: analytical functions

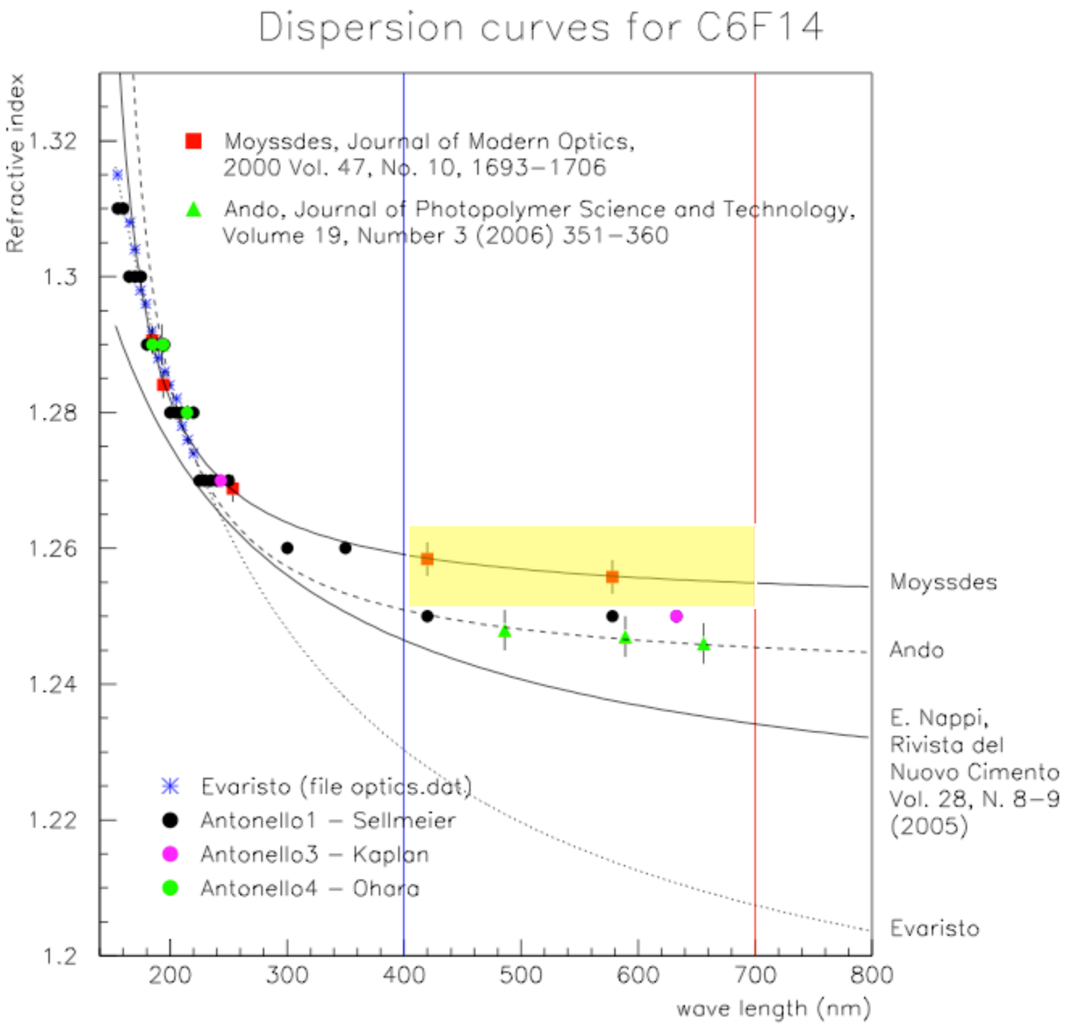
~ 1 mr difference ⇒ C_5F_{12} mandatory!

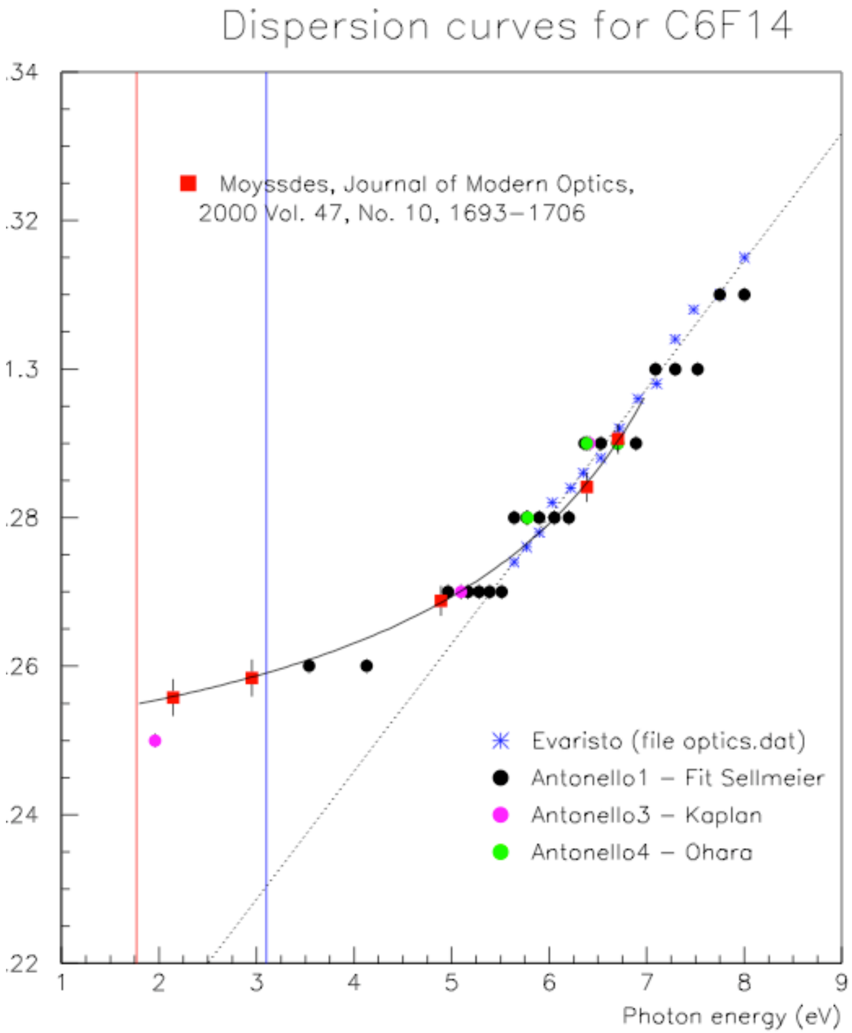
Idea: why not visible light ?

- Much reduced cromatic error
- Longer absorption length -> higher number of p.e.

- Higher cost due to photomultiplers

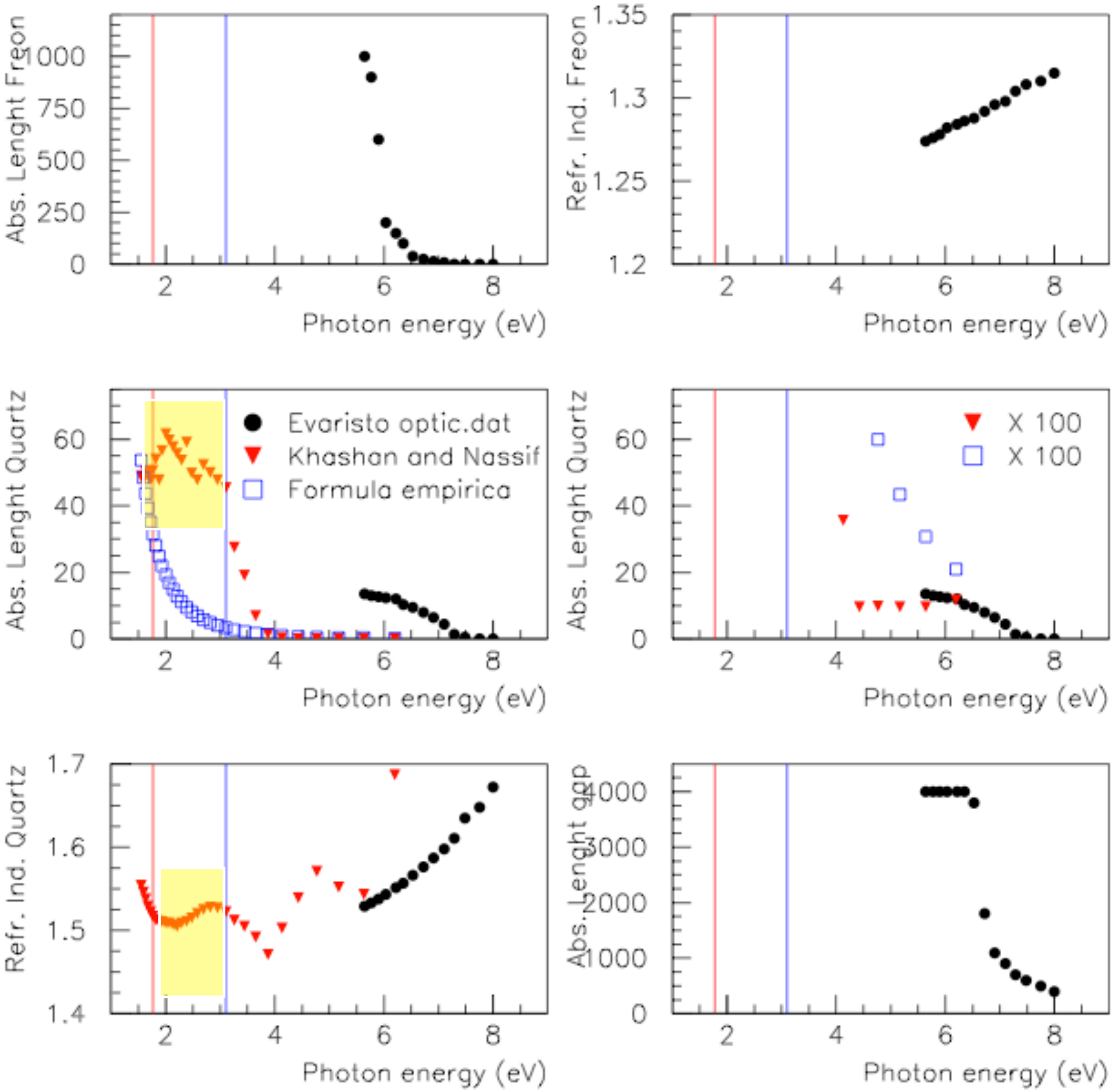
Refraction index: freon





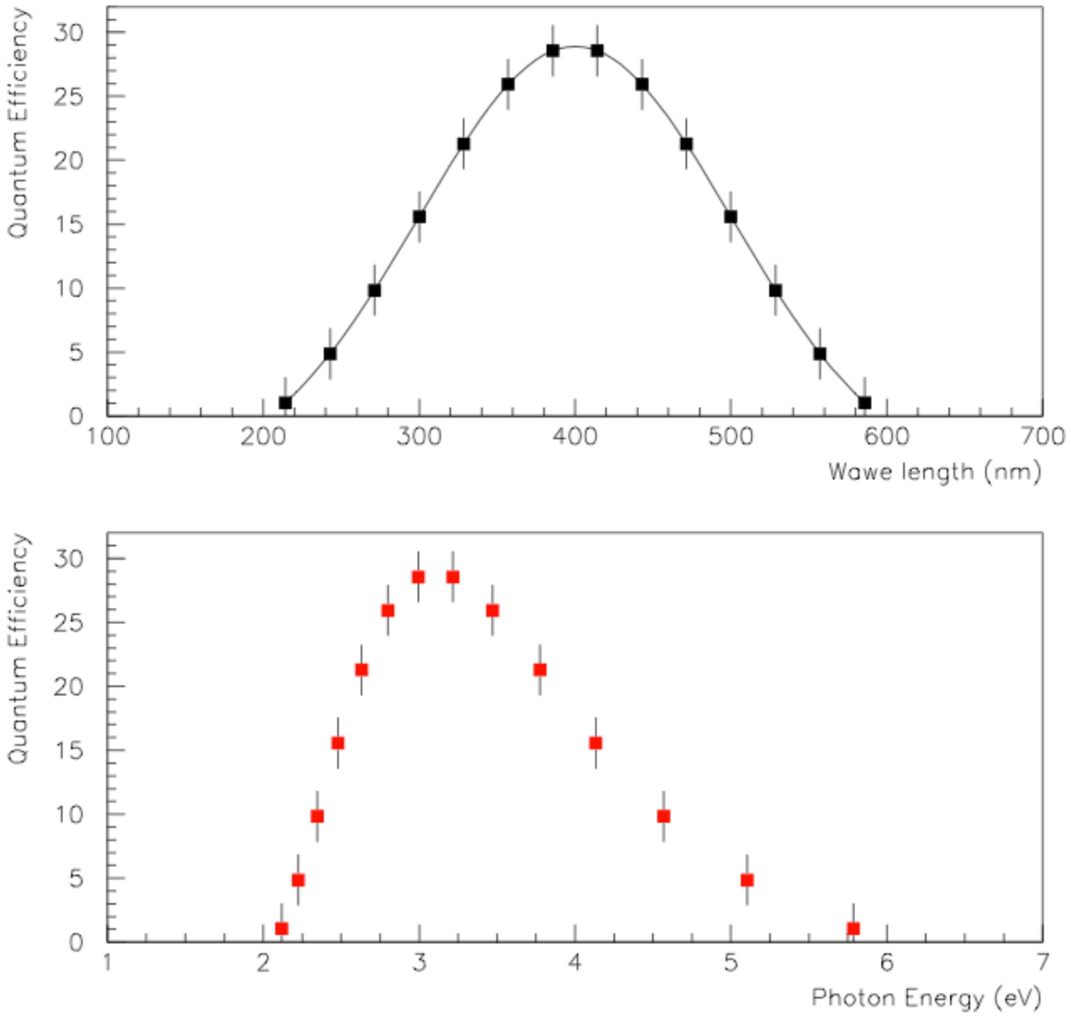
Simulation based on most conservative n (Moyssdes)

Refraction index: quartz



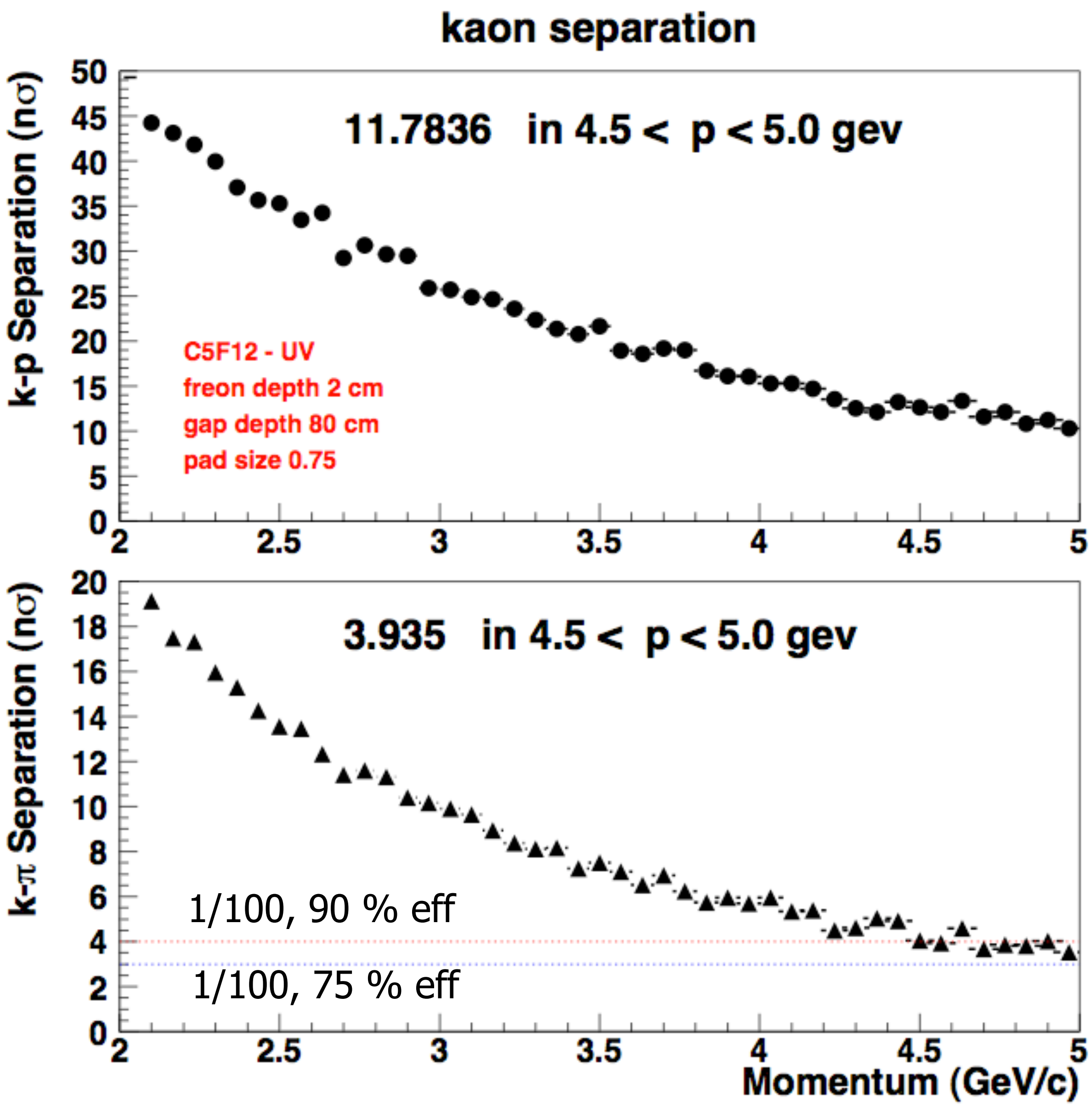
Quartz absorption length and refraction index from
Khashan and Nassif, Optic communications 188 (2001) 129

p.e. quantum efficiency

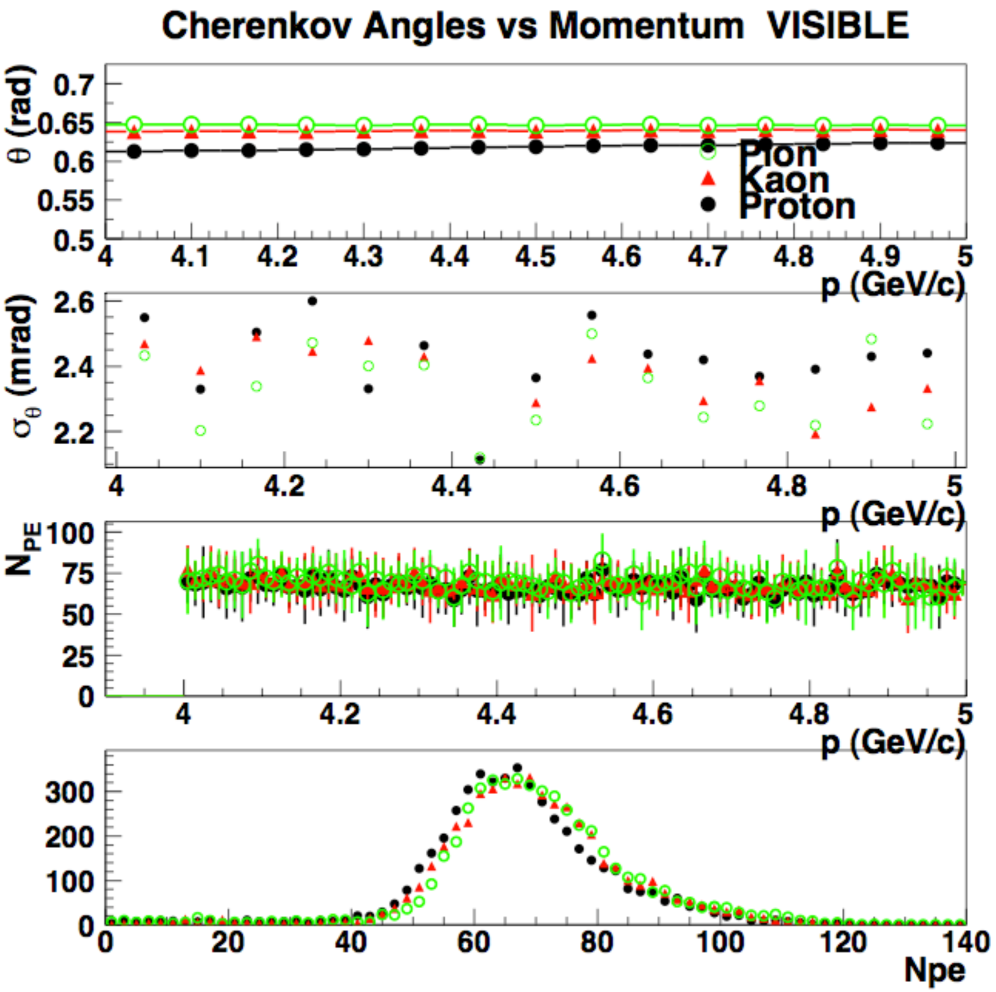


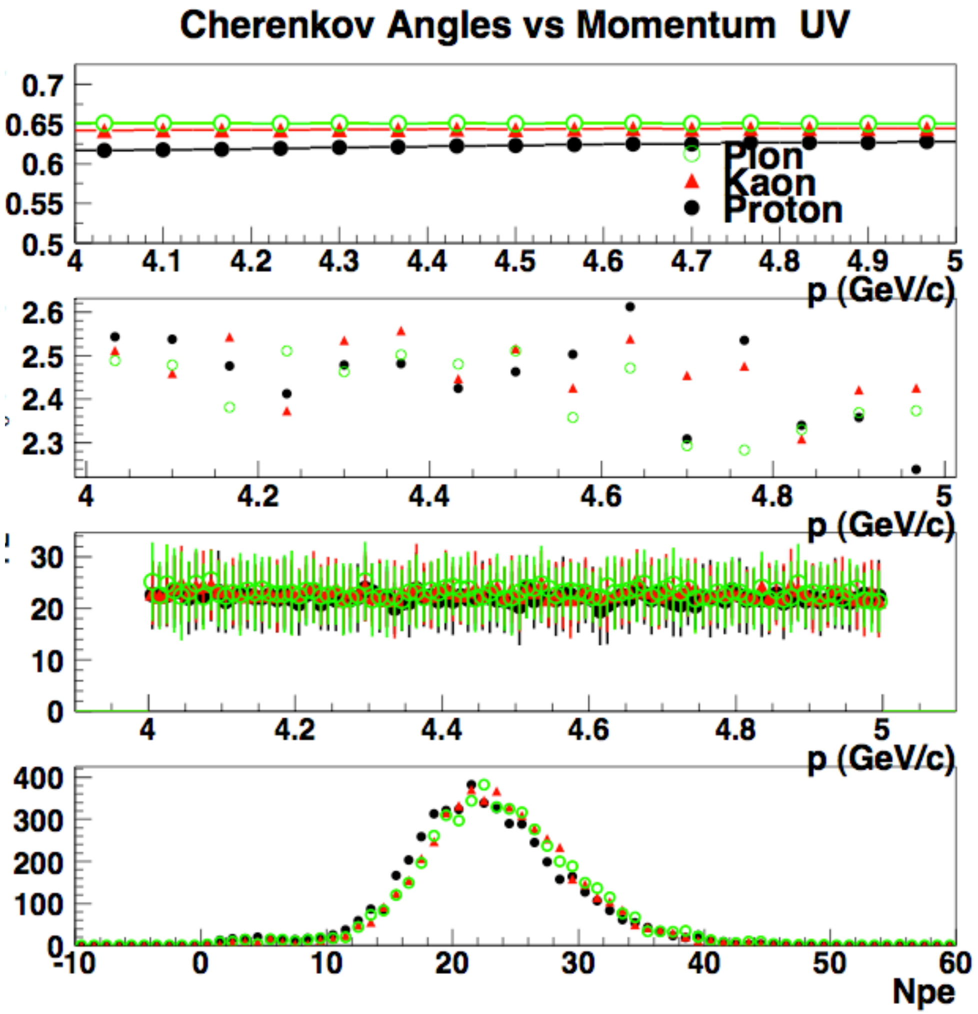
Typical spectrum for a generic PM

Just an example…..



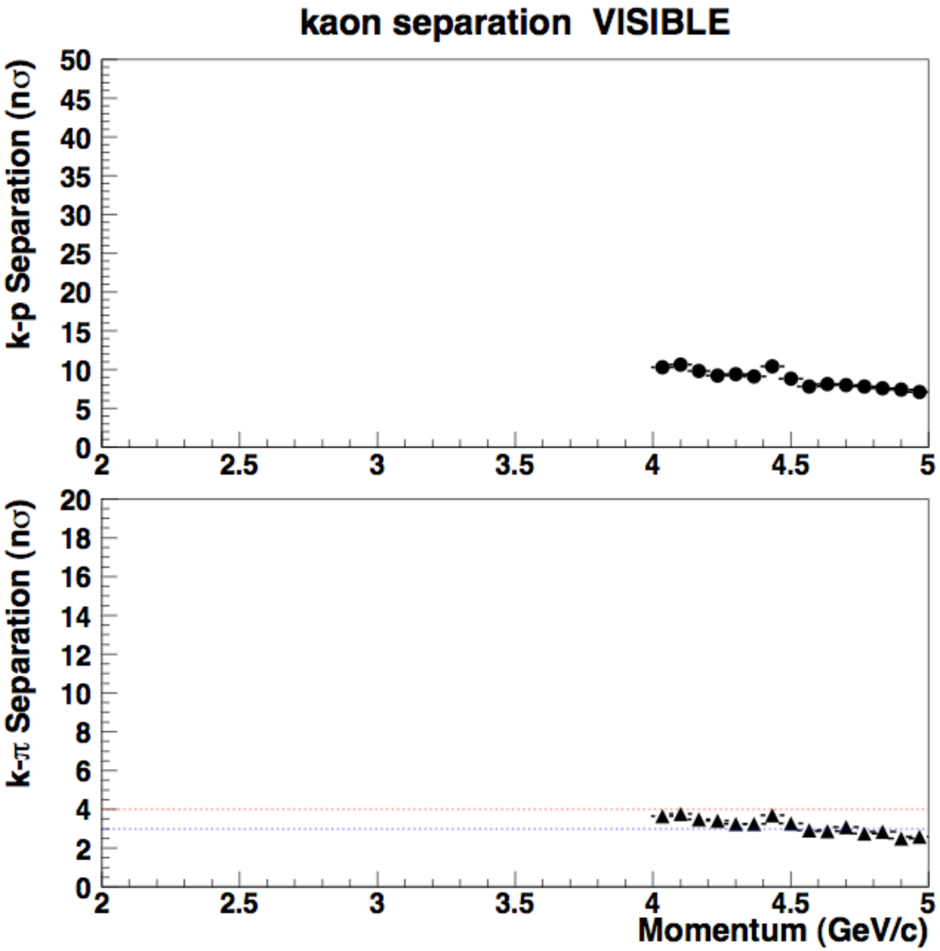
UV vs visible regime

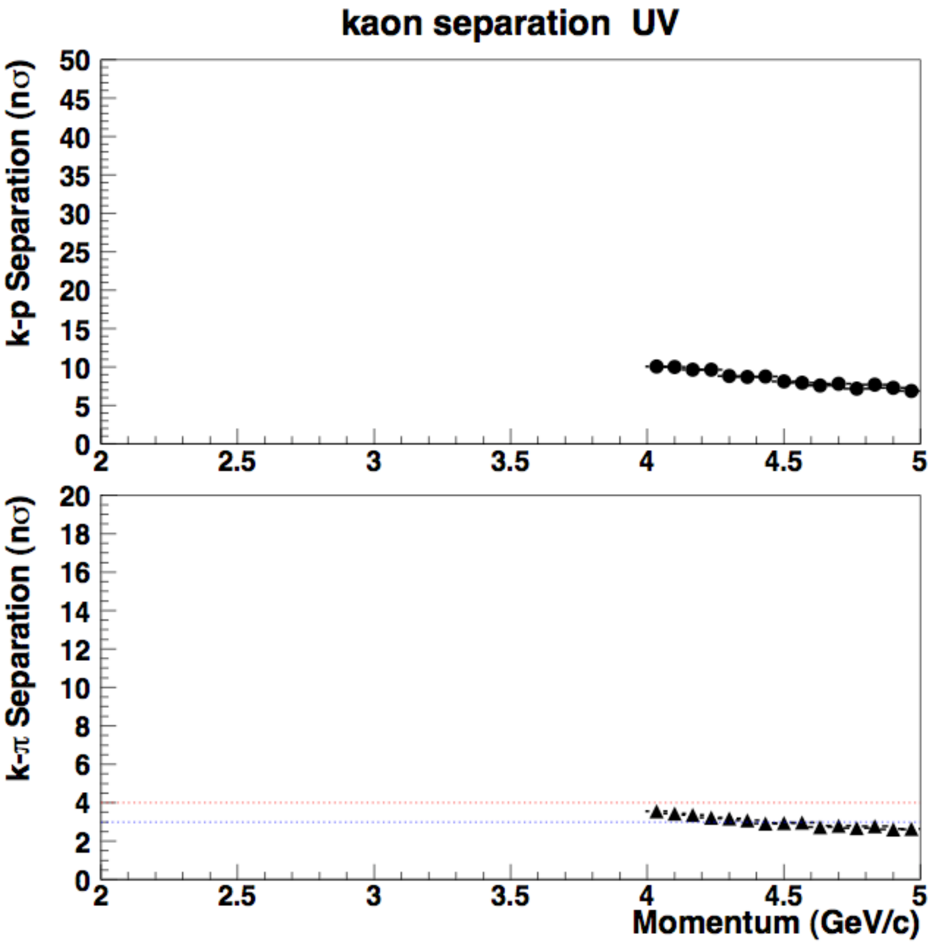




Accounting in addition for 0.65 efficace detection efficiency

UV vs visible regime



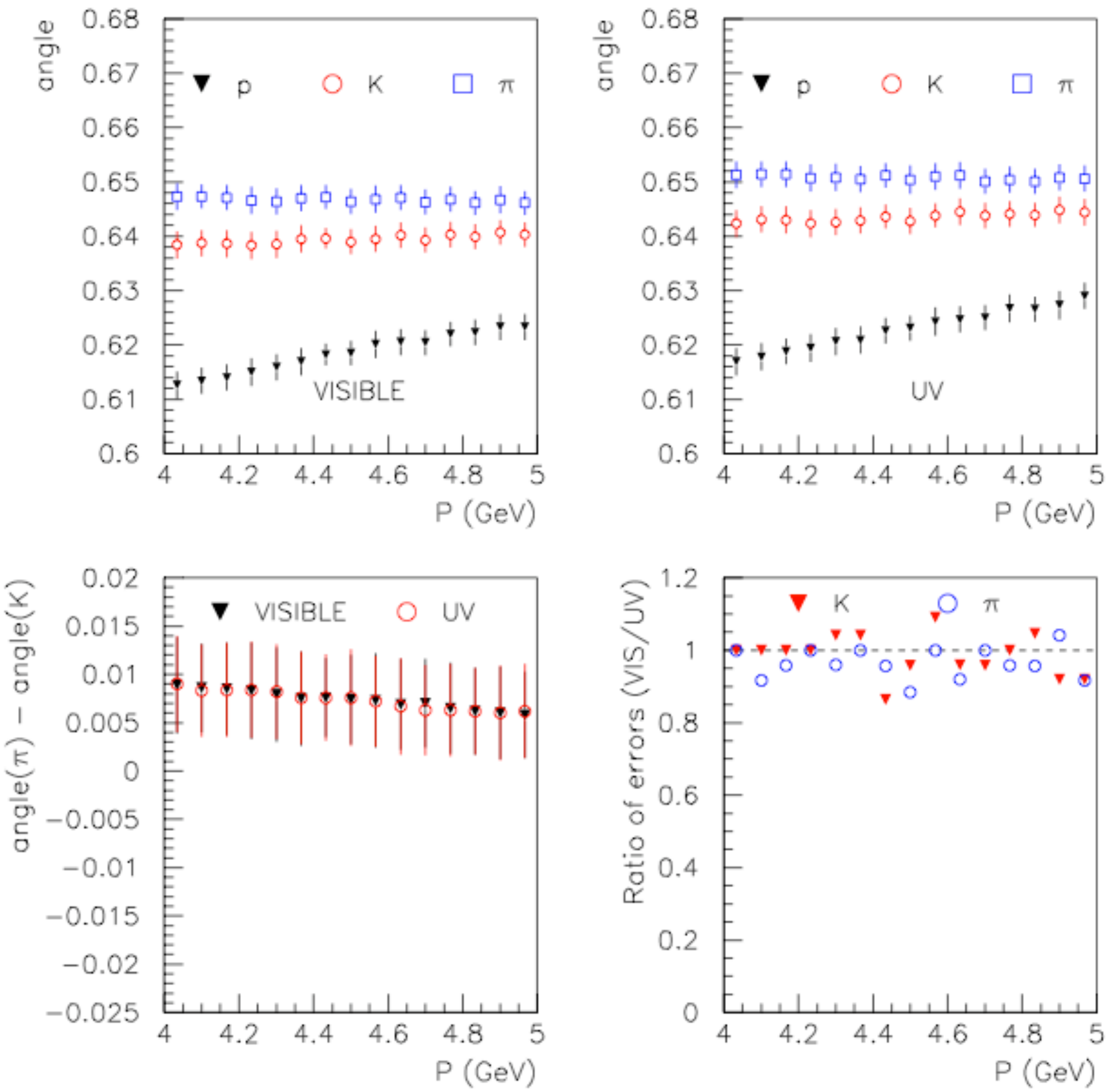


No improvement at a variance with expectations:

- Reduced chromatic error (uniform refr. Index)
- Increased photon number (larger abs. length)

UV vs visible regime

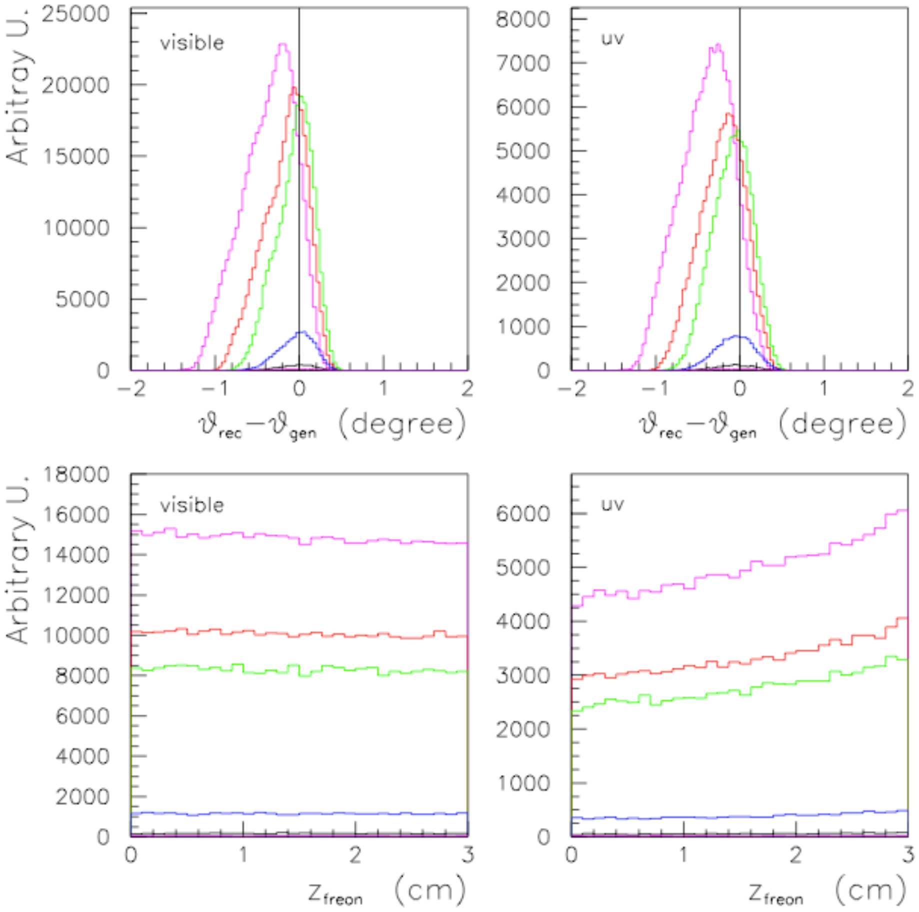
PAD size 1 cm



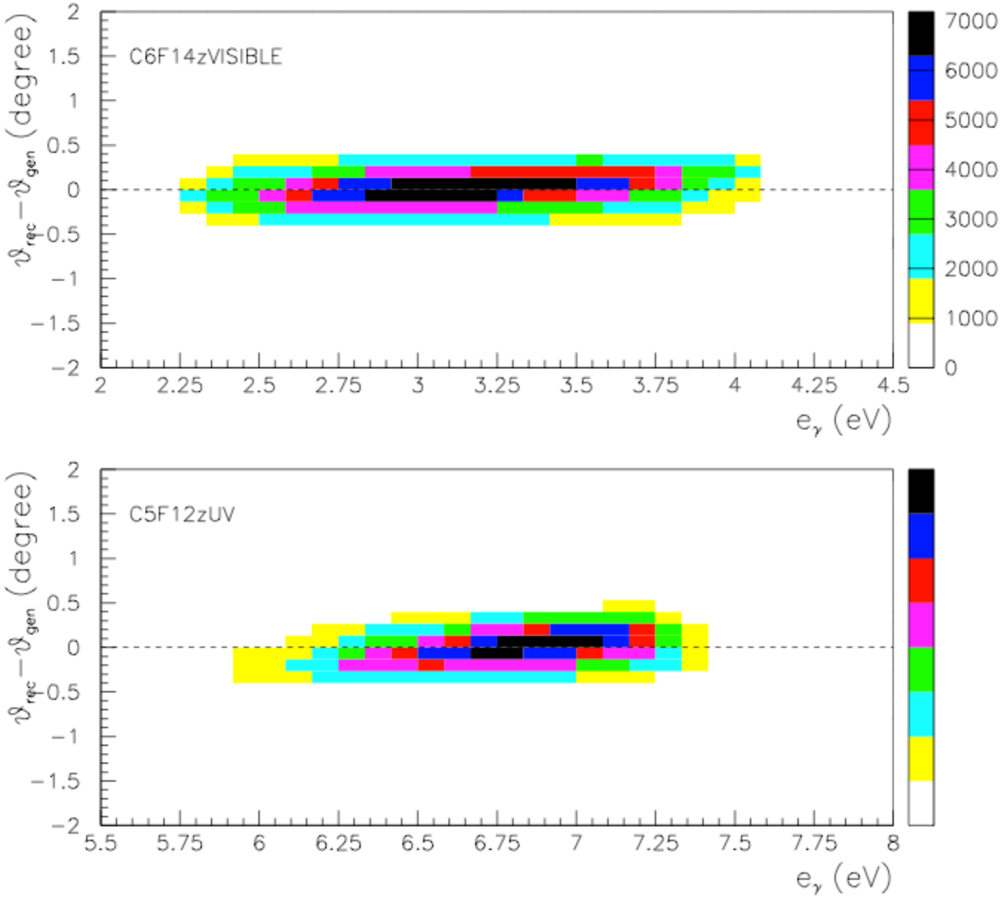
No difference in the Cerenkov angle resolution

Cerenkov angle reconstruction

Vs. track angle

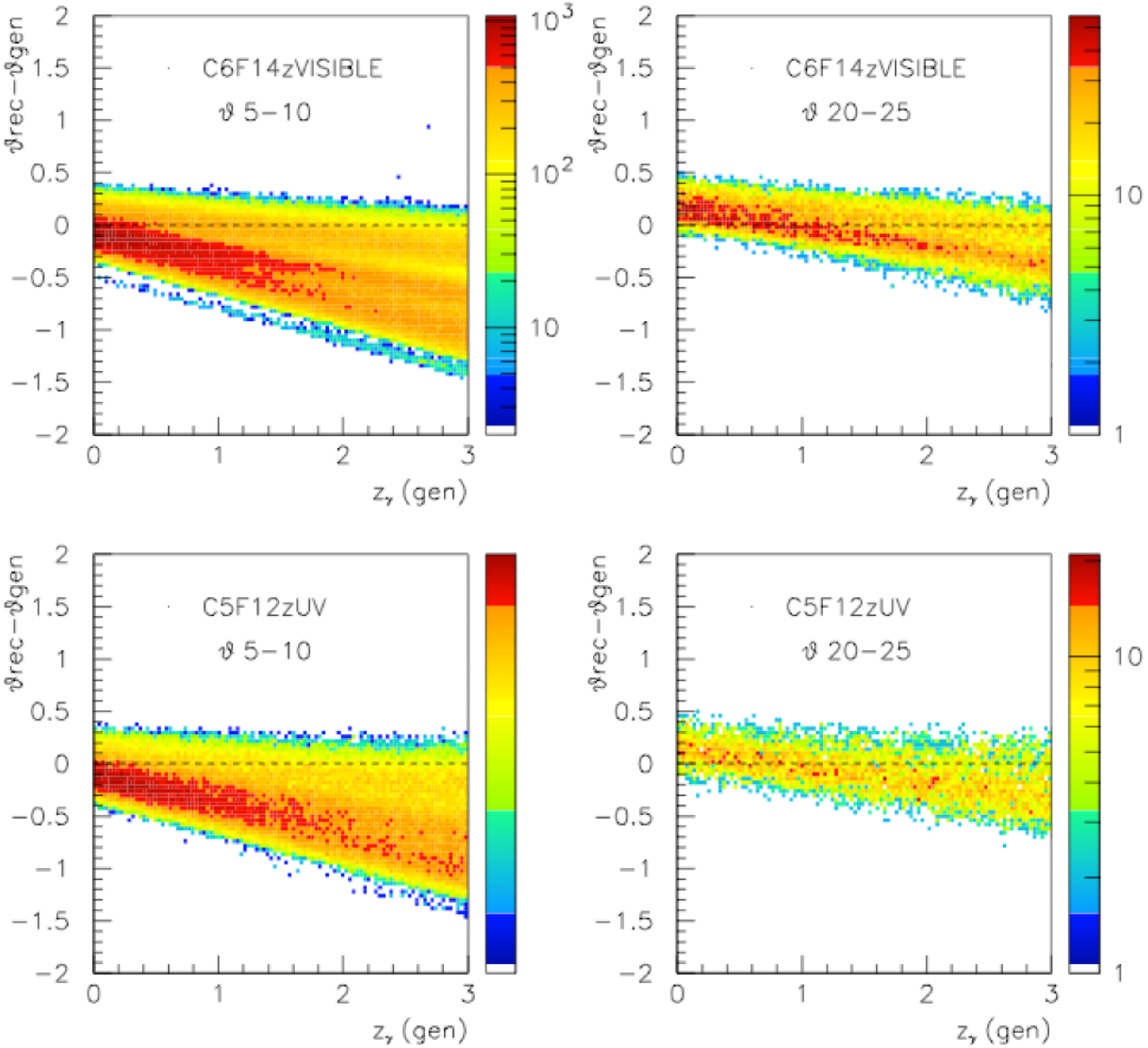


Vs. photon energy



Cerenkov angle reconstruction

Vs. emission point



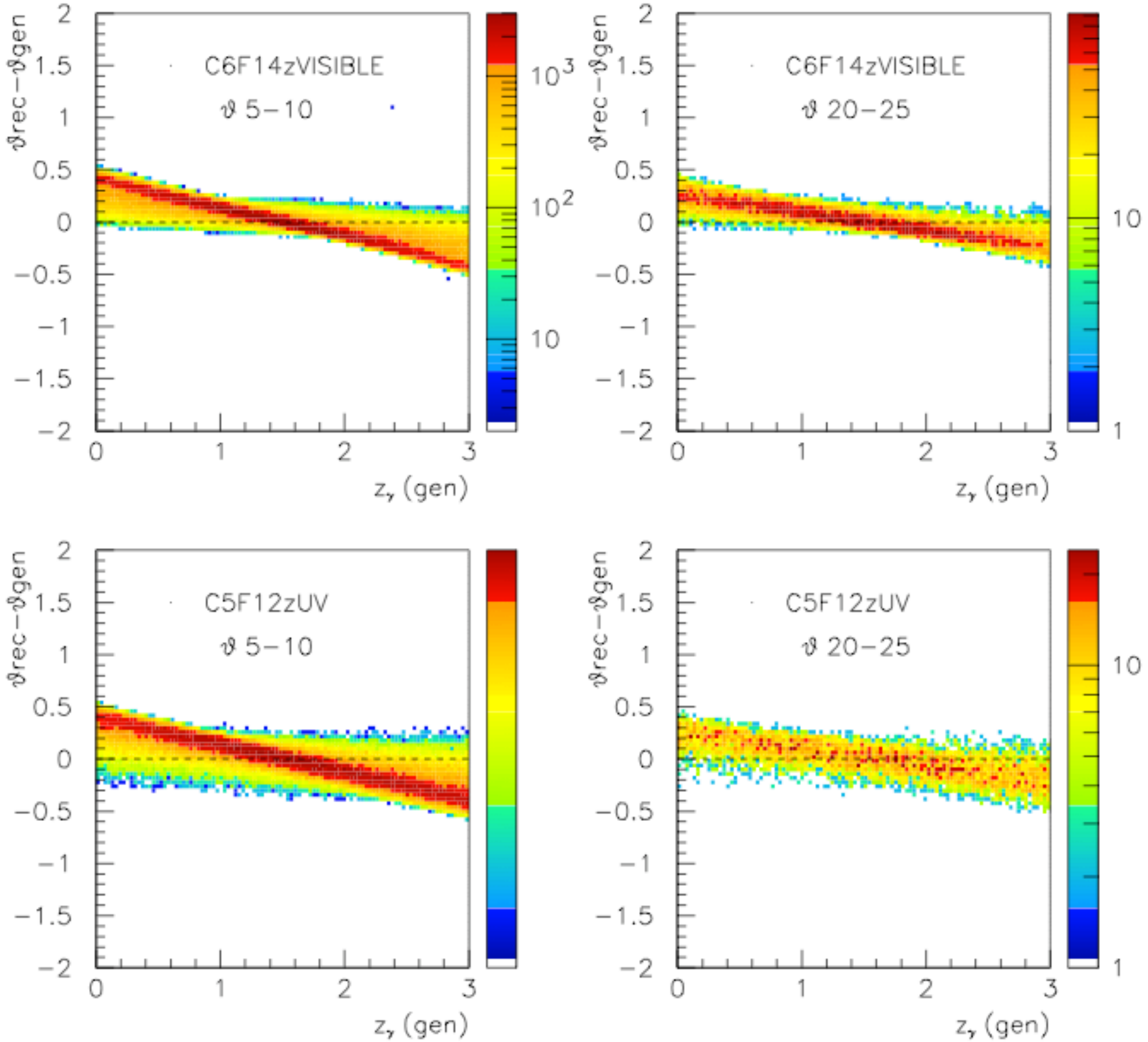
Cerenkov angle reconstruction

Particle impact point z fixed at -5 cm (before freon)

move z to 0 cm (freon surface)

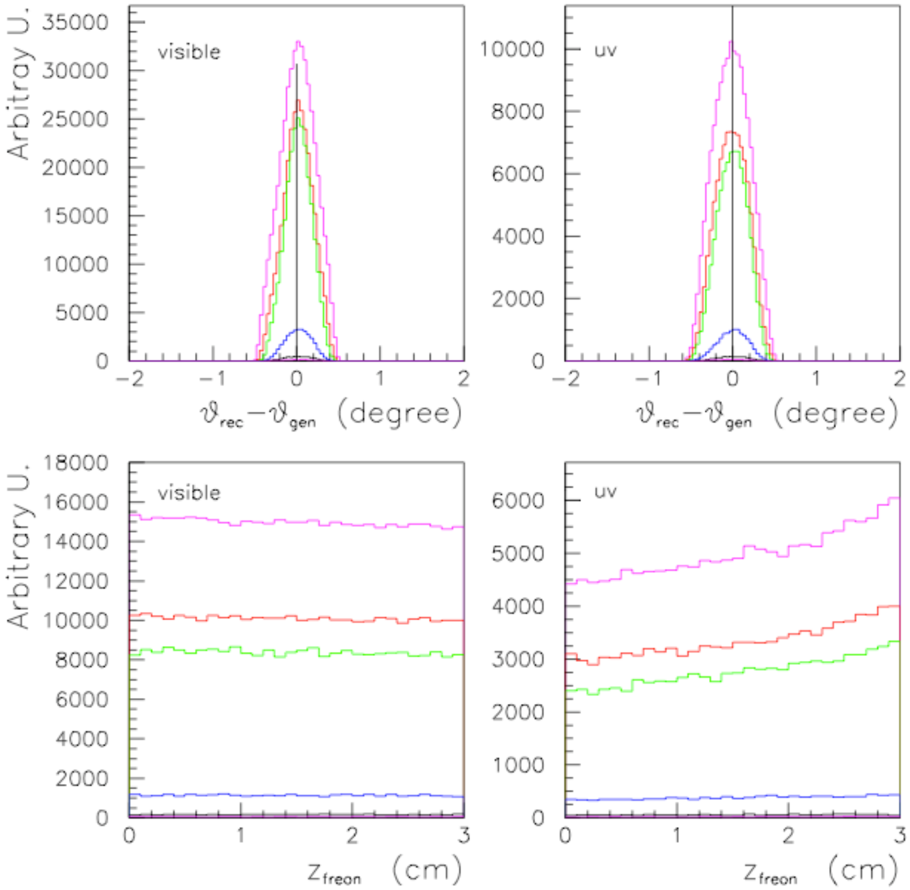
Cerenkov angle reconstruction

Vs. emission point

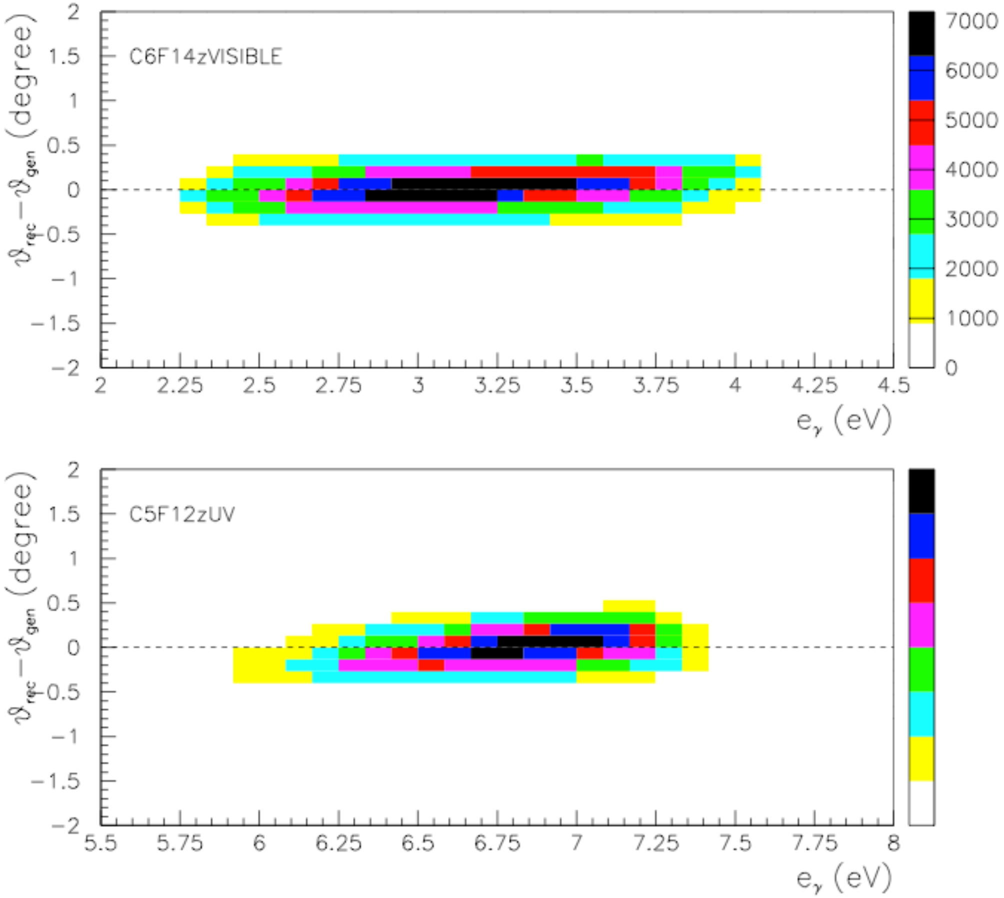


Cerenkov angle reconstruction

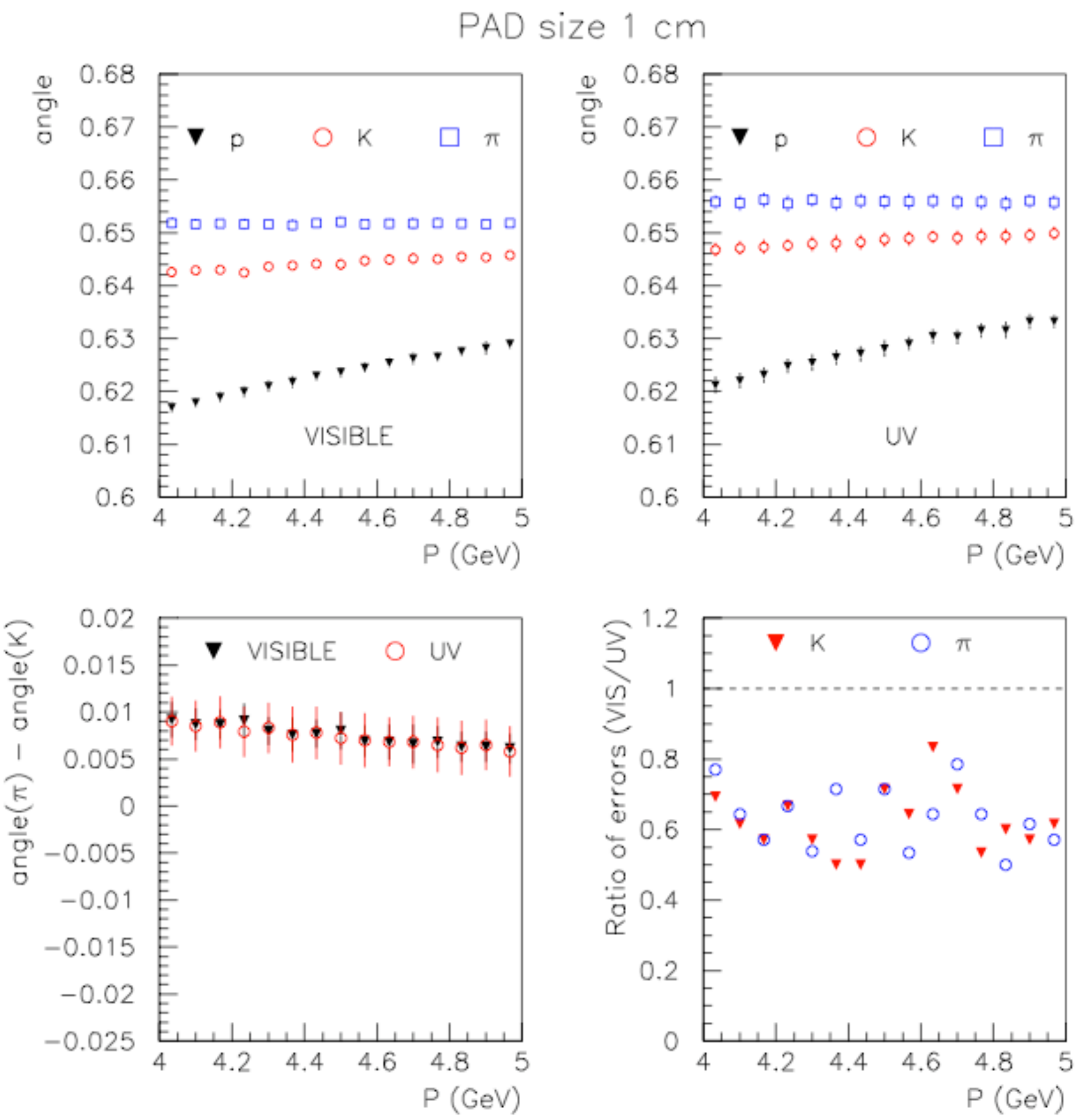
Vs. track angle



Vs. photon energy

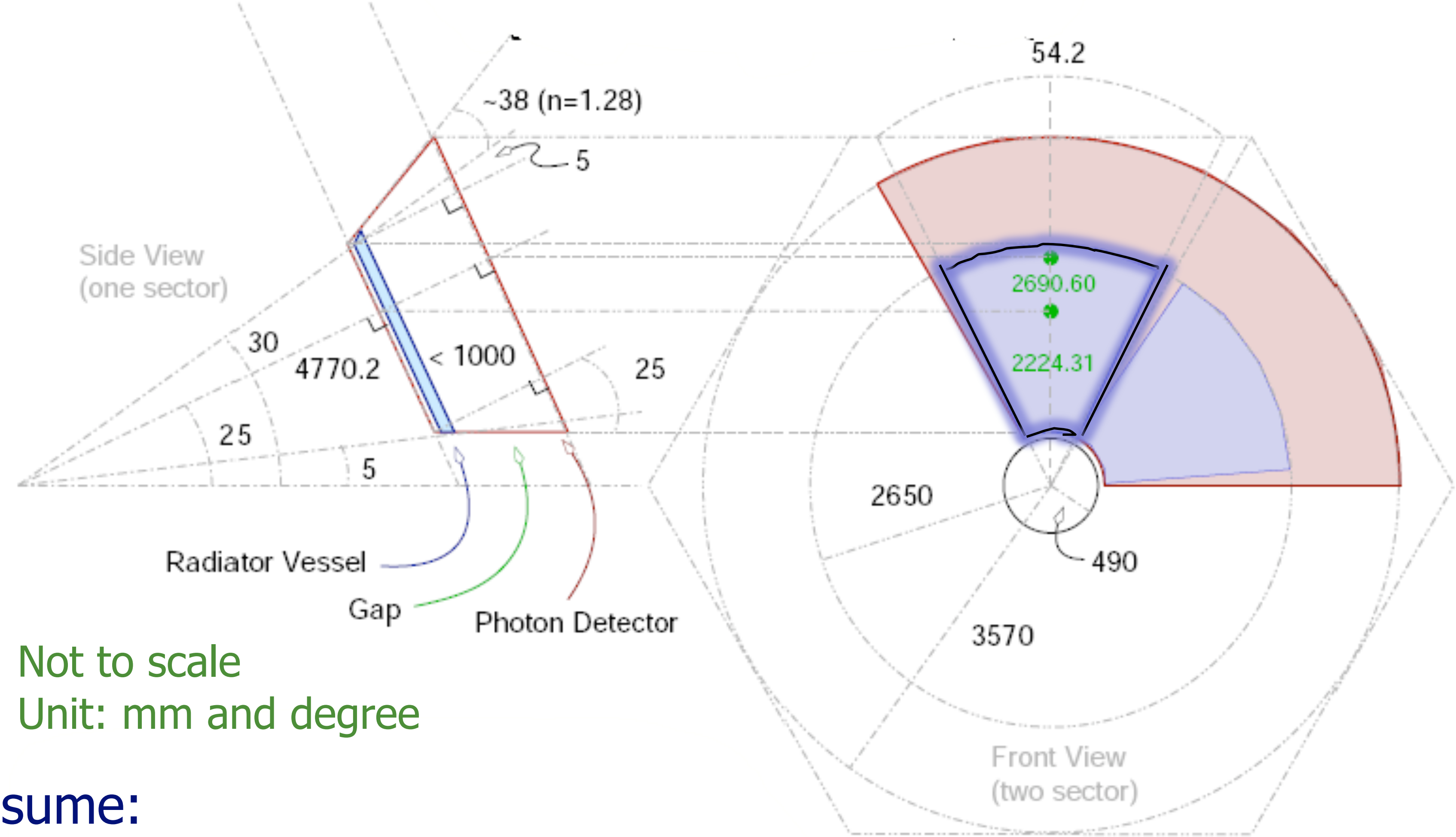


UV vs visible regime



Cerenkov angle resolution now scales as expected

Geometry needs refinement: 1



Not to scale
Unit: mm and degree

Assume:

- Two radiators (only 1 simulated); one per sector
- Detector covers up to 2 sectors (detect photons from both radiators)
- Radiator Polar acceptance: 5° ÷30° ⇒ fix radiator size ~ 4 m^2
- Max gap length = 120 cm

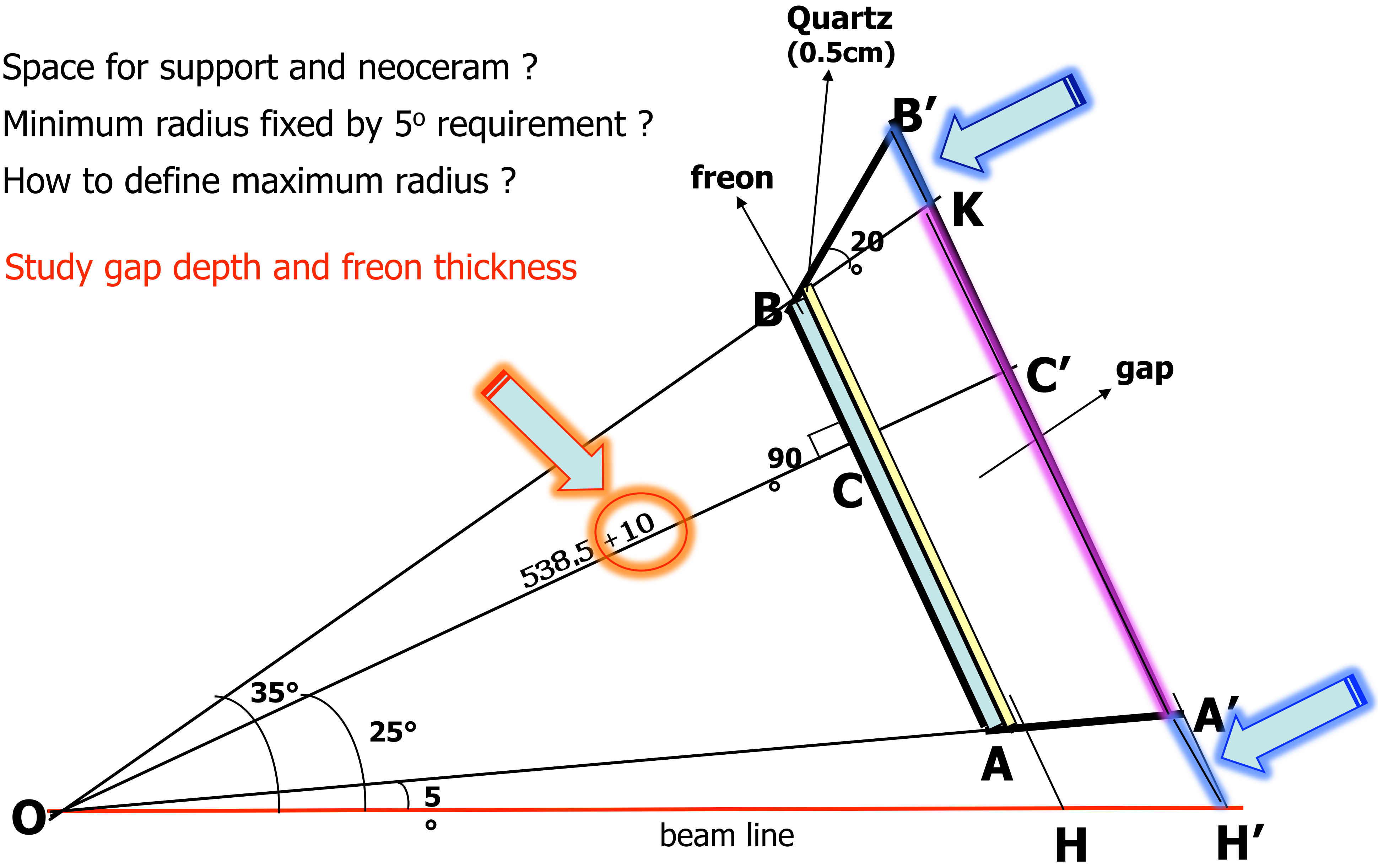
Geometry needs refinement: 2

Space for support and neoceram ?

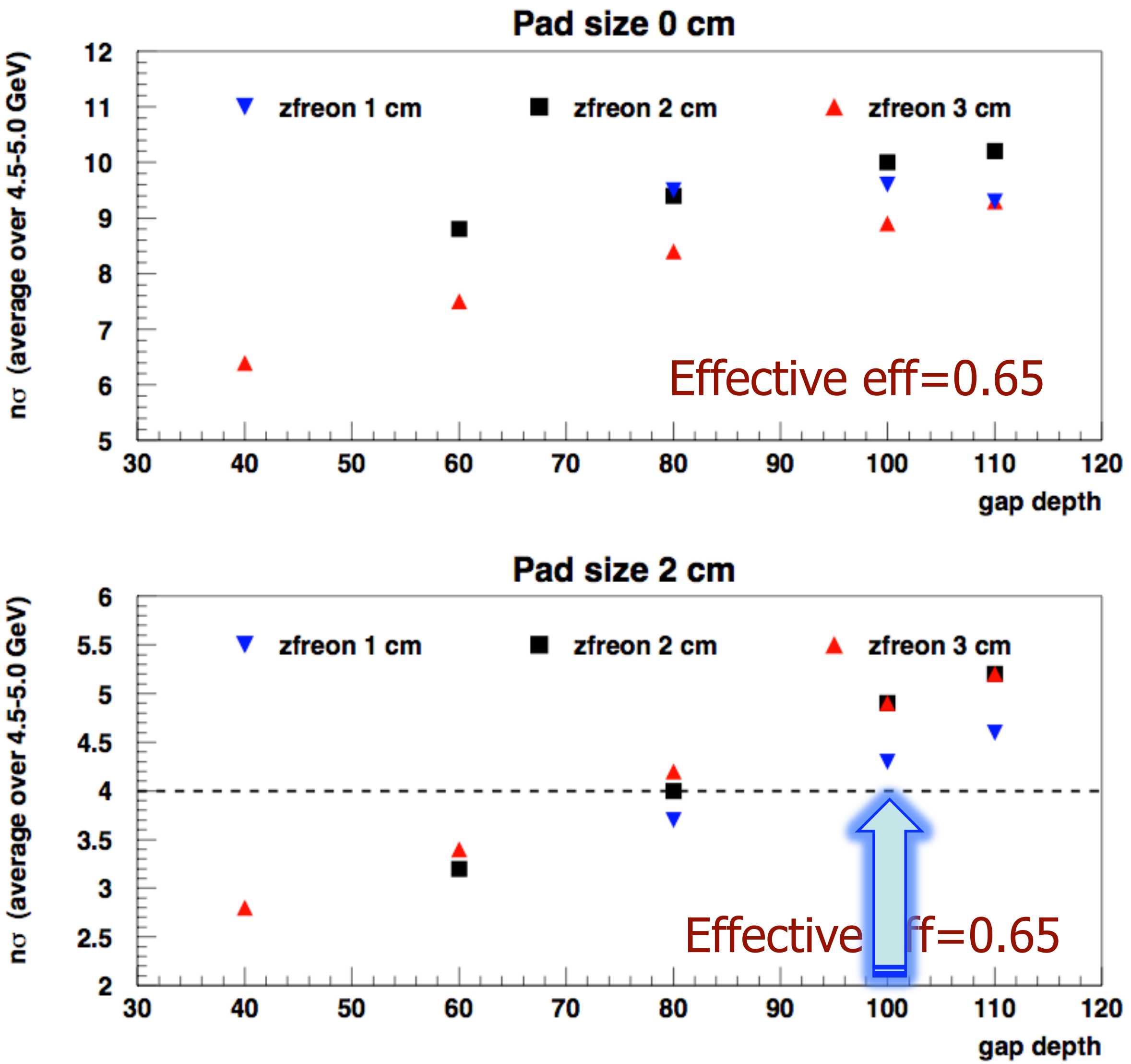
Minimum radius fixed by 5° requirement ?

How to define maximum radius ?

Study gap depth and freon thickness



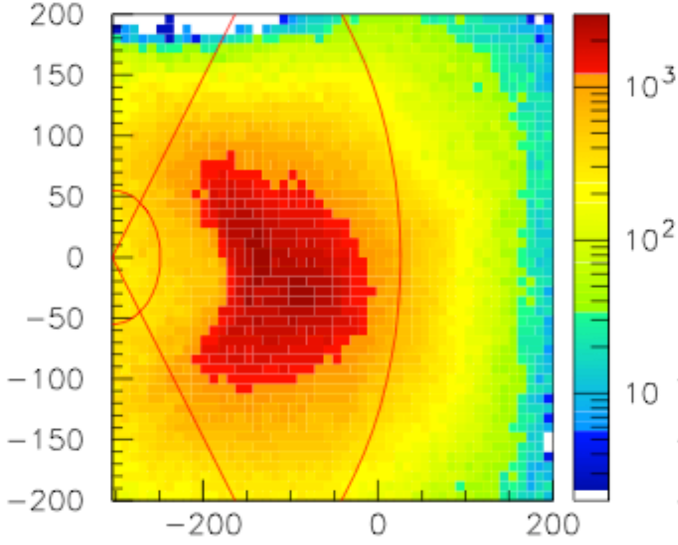
Average πk separation [4.5-5 GeV]



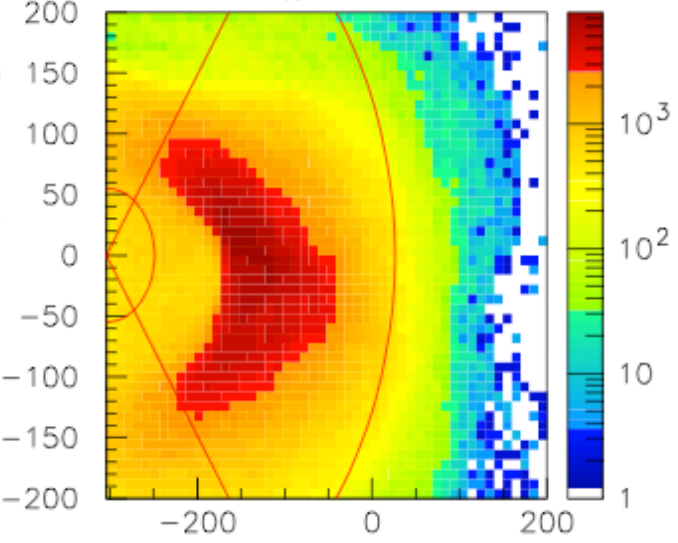
Minimum pad size 2x2 cm^2 gap (assumed)
5σ separation with 100 cm and 2 cm freon

Photon spatial distribution

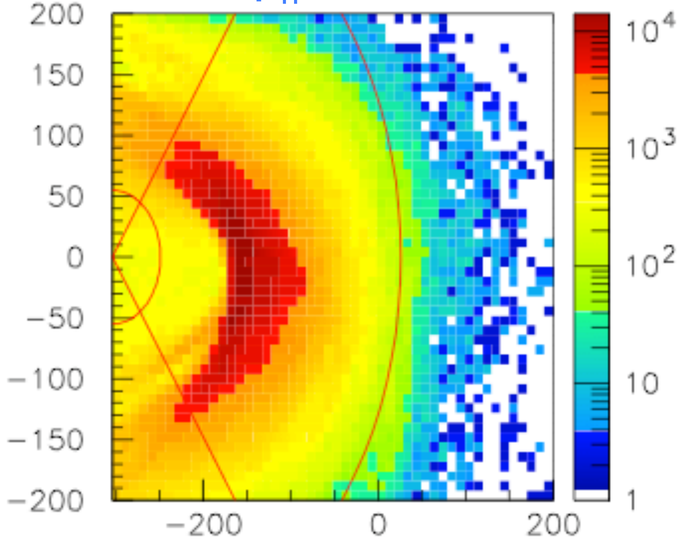
$2<p_h<3$ GeV



$3<p_h<4$ GeV



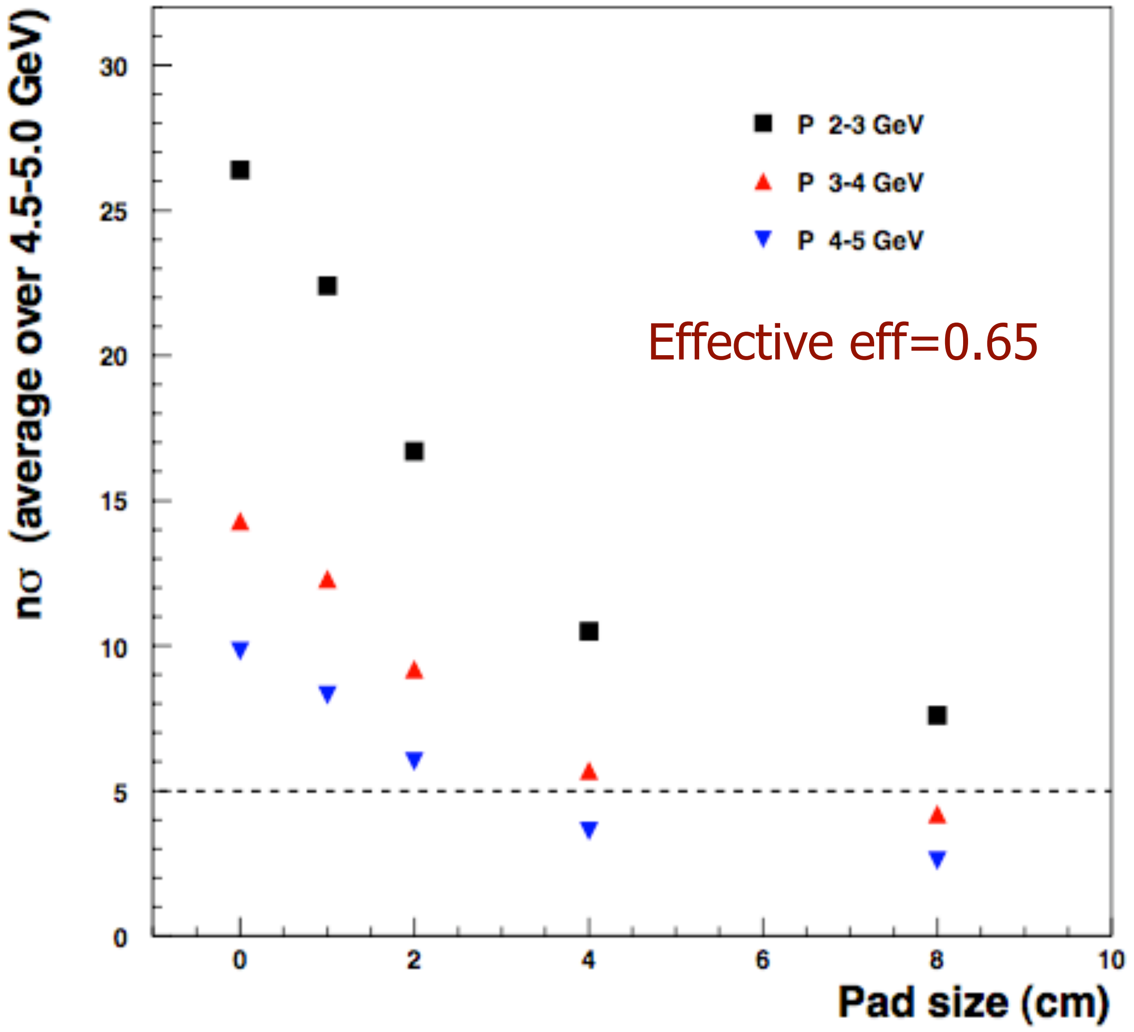
$4<p_h<5$ GeV



Photon detector area > 10 m^2 with 2500 2x2 cm^2 PM per square meter and > 100 $ each: 2.5 M$ just enough

Correlation between track energy/angle and detector area spanned by photons might lead to cost optimization

Average πk separation



Small "pad" size is needed only in the restricted area spanned by photon from large momentum particles

Conclusions and Outlook

Previous pessimistic estimations affected by a wrong impact z coordinate

Study the C6F14 and visible light options just started

- A hybrid (visible + UV photons) solution under test
- To be compared with C5F12 and UV light at same conditions
- Estimate the optimal geometrical parameters
  - freon thickness
  - gap length
  - detector/pad size
- Toward real experimental conditions
  - π,p,k with their specific spectra
  - Real particle multiplicity
- Limit the total cost
  - define degrees of freedom and limiting conditions

Radiation thickness

	Thickness (cm)	X_0 (%)
Entrance window		
Al	0.05	0.5
Rohacell51	5	2
Al	0.05	0.5
Radiator		
Neoceram	0.4	3
C_5F_{12}	2	10
Quartz	0.5	4
Gap		
CH_4	80	0.001
Photon Detector		
Pad NEMAG10	0.08	0.4
GEM chamber	1	0.6

Total radiation thickness of the proposed RICH: ~20% X_0

Costs - Very Preliminary!!

Class12/Hall A

Radiator: 36-48 (min.-max. volume), 24 (surface)
Detector: 13 (surface), 4 (chs)

	Hall A RICH	Factor	Class12 RICH
Readout	95	4	380 (15%)
MWPC: Pads Planes	20	10	200 (8%)
MWPC: Parts (Macor Insulator)	15	10	150 (6%)
Freon (C6F14)	20	40	800 (33%)
Quartz+Neoceram	30	20	600 (24%)
Mechanical Structure	30	10	300 (12%)
Evaporation Fac.	*500*	*1*	*500 (exist)*
Freon Recirculation System	*20 (?)*	*1.5*	*30 (?)*
Total	**210+520**		**2420+530**

k$
(estimation from Lire, CHF, $ and Euro)

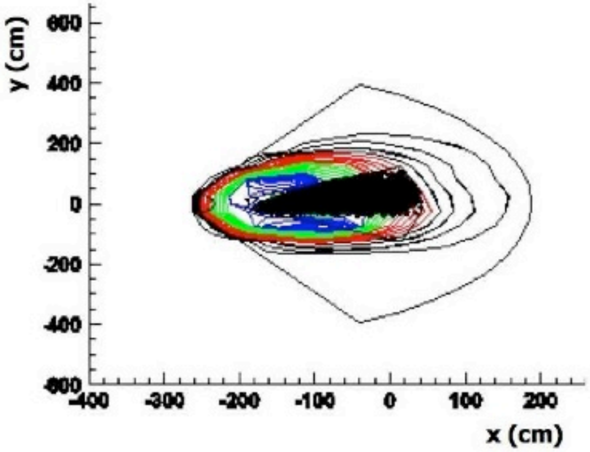
GEM ~ 1.2 x MWPC

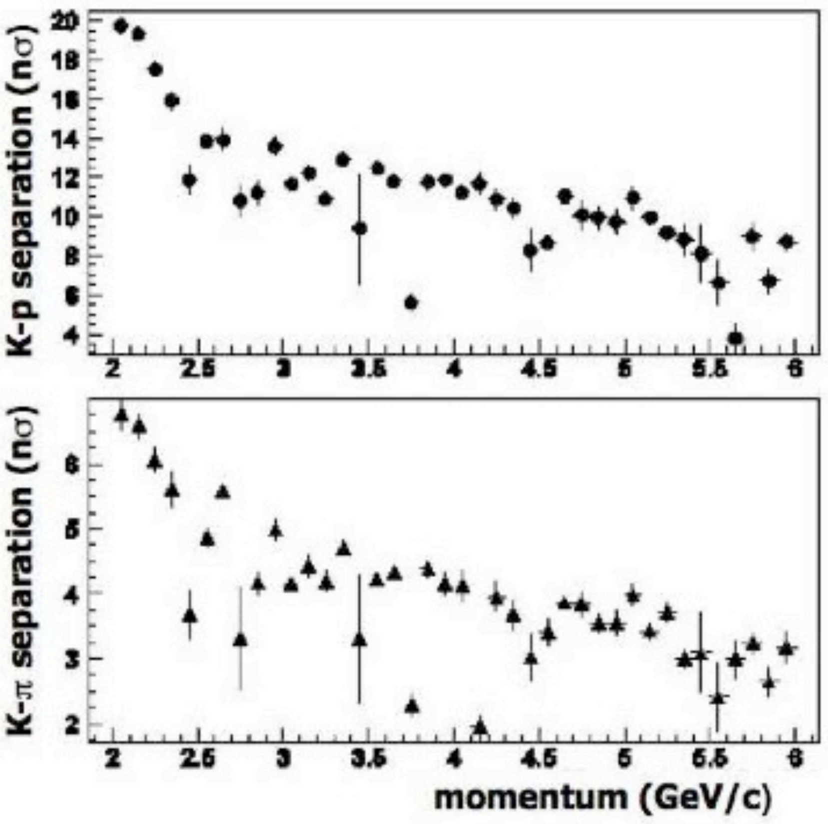
K-π Separation_old

Angle reconstruction error vs:

10K **generated** events

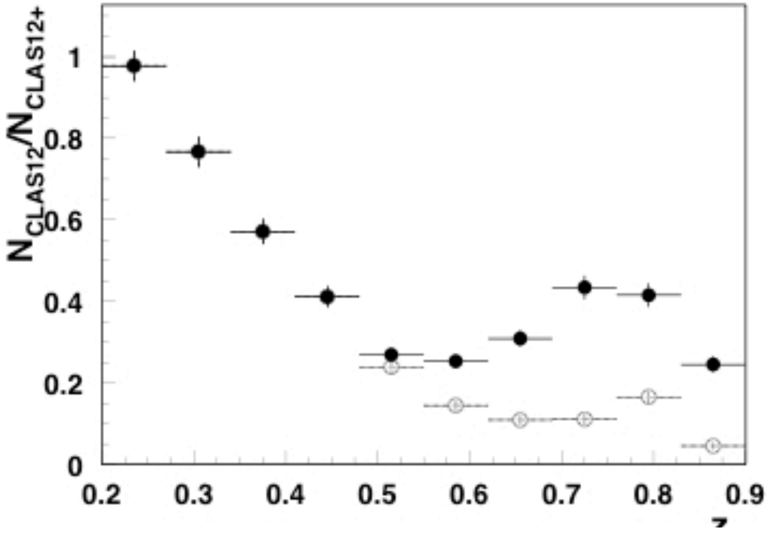
- Radiator Thickness = 3 cm
- Gap length = 80 cm
- Pad/Pixel size = 0.75 cm

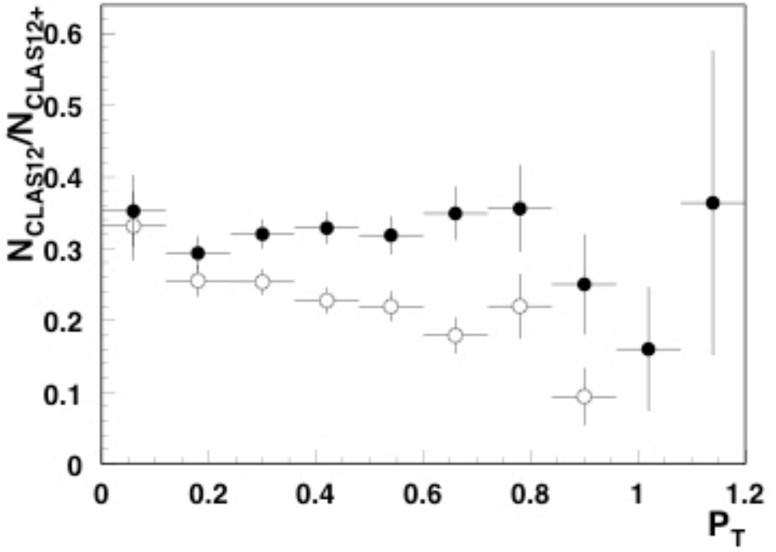


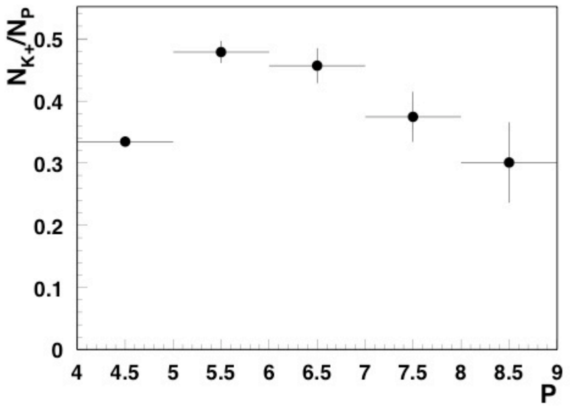


Approved Experiments requiring a RICH

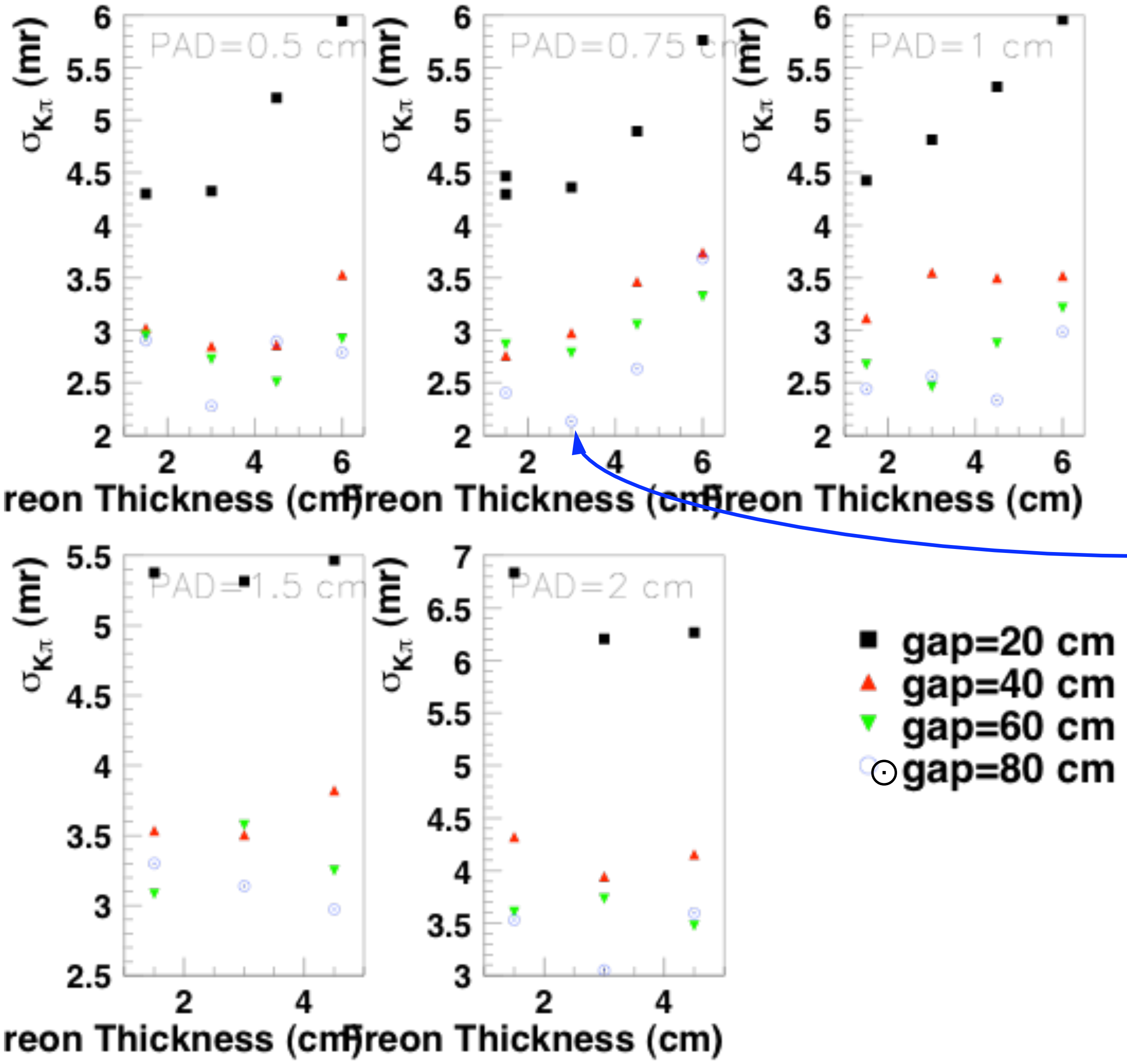
PR-09-007 Studies of partonic distributionsusing semi-inclusive production of kaons.
PR-09-008 – Studies of the Boer-Mulders Asymmetry in Kaon Electroproduction with Hydrogen and Deuterium Targets.
PR-09-009 Studies of Spin-Orbit Correlations in Kaon Electroproduction in DIS whit polarized hydrogen and deuterium targets.







Radiator Thickness / Proximity GAP



- C_5F_{12}
- Single sector radiator
- 2 sectors photon detector (26 m^2)

Angle reconstruction error vs:

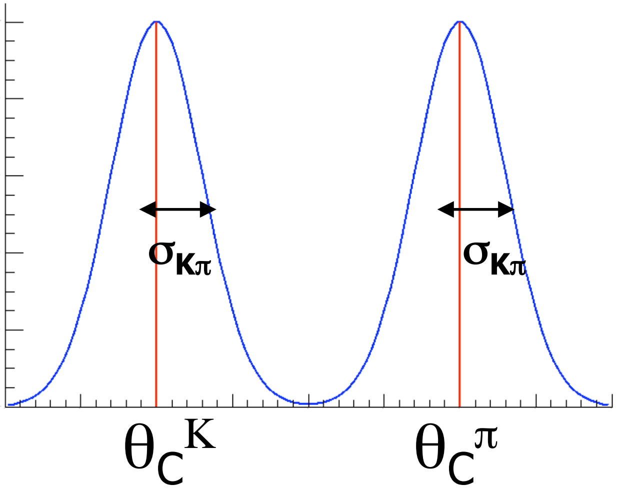
- Radiator Thickness,
- Gap length
- Pad/Pixel size

Optimal combination:

Freon Thickness ~ 3 cm

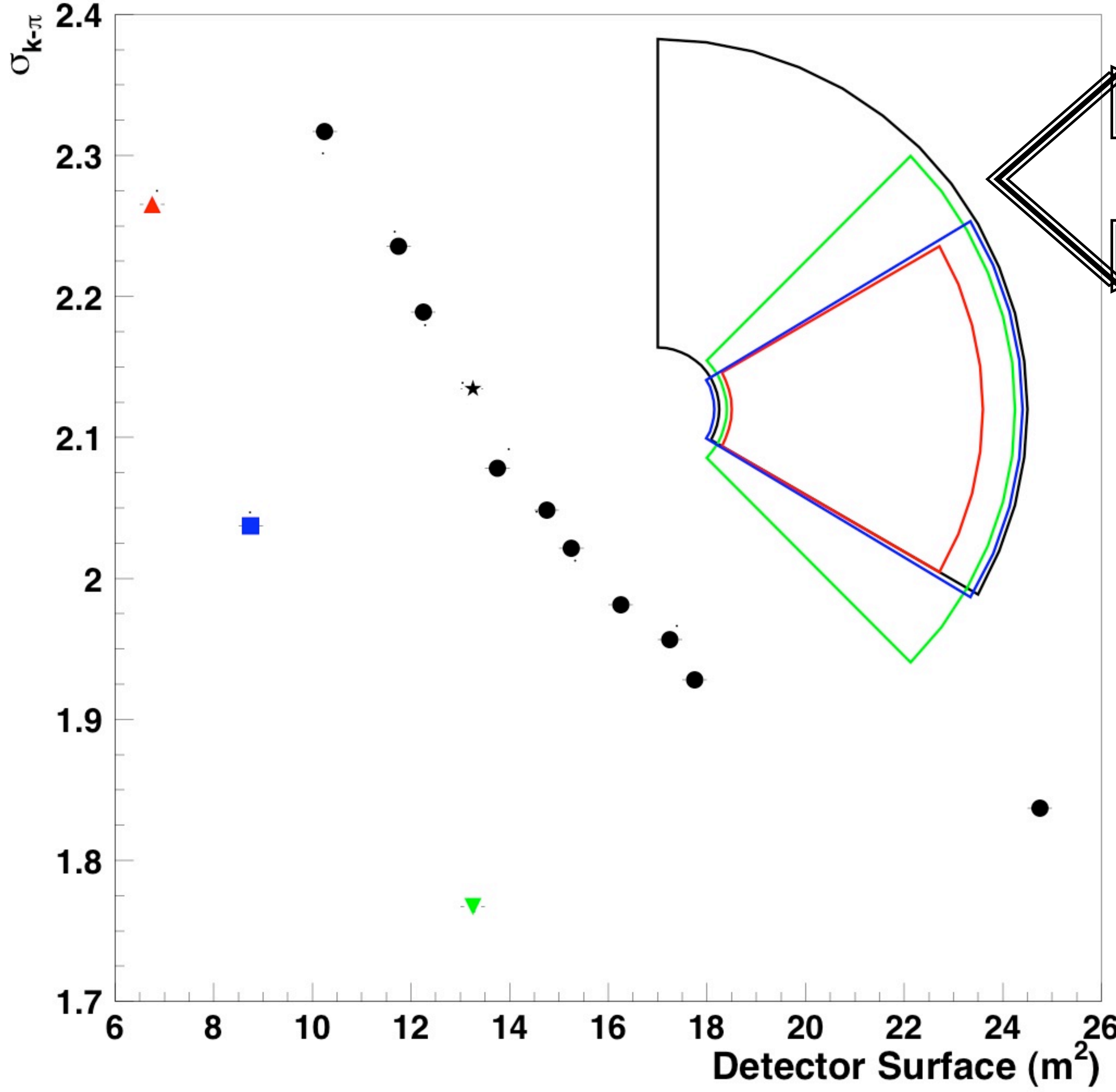
GAP Length ~ 80 cm

PAD size < 1 cm



Note: MC statistics is poor!

Photon Detector Size



The drawings inside the plot represent different detector sizes simulated

Black dots: represent the black arc at different external radius

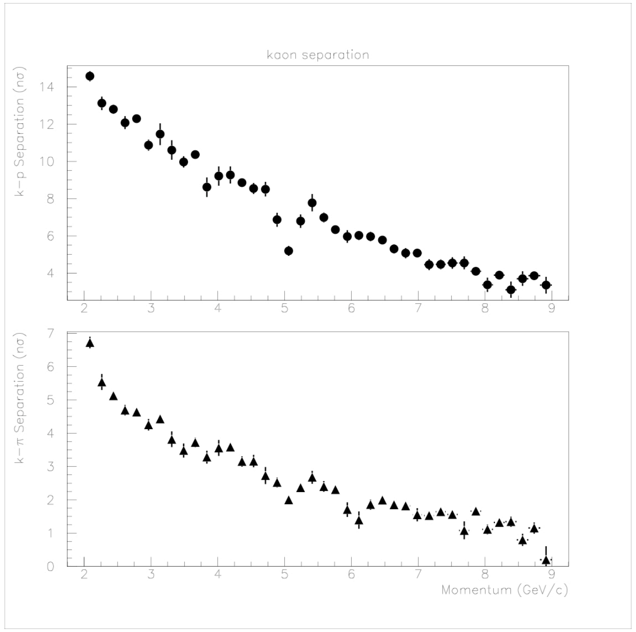
Red triangle: corresponds to the red single sector

Blue square: corresponds to the blue single sector with optimal external radius

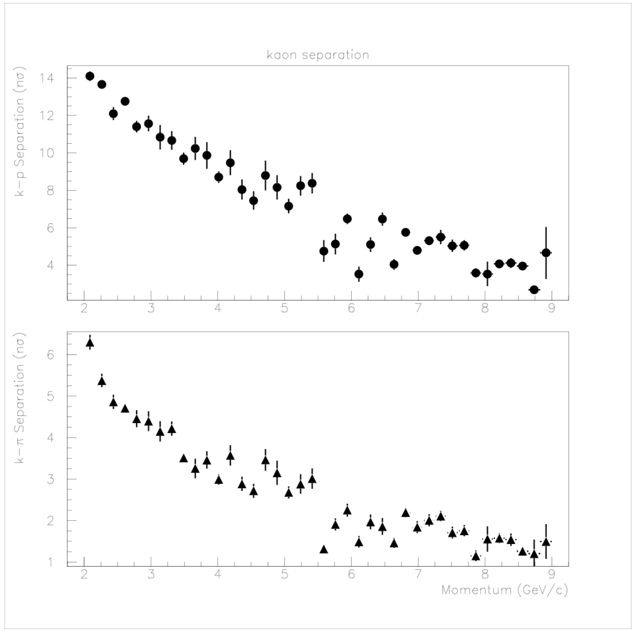
Green Triangle: Optimal sector (± 45 degree) and external radius

K-π Separation

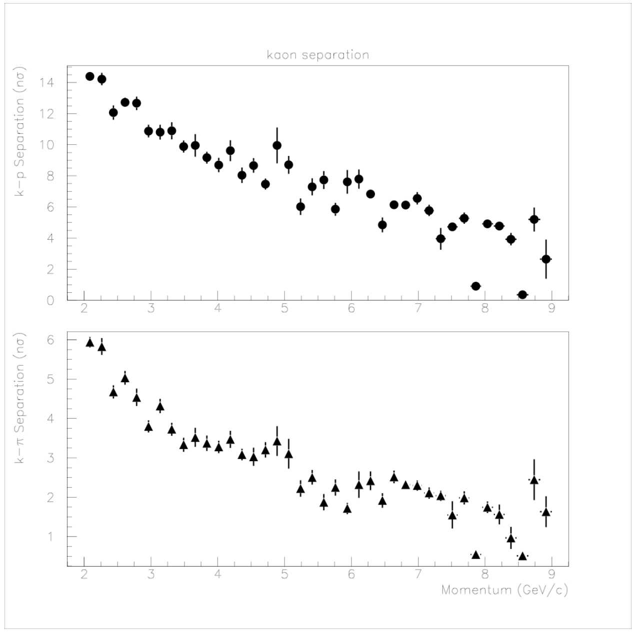
80_1.5



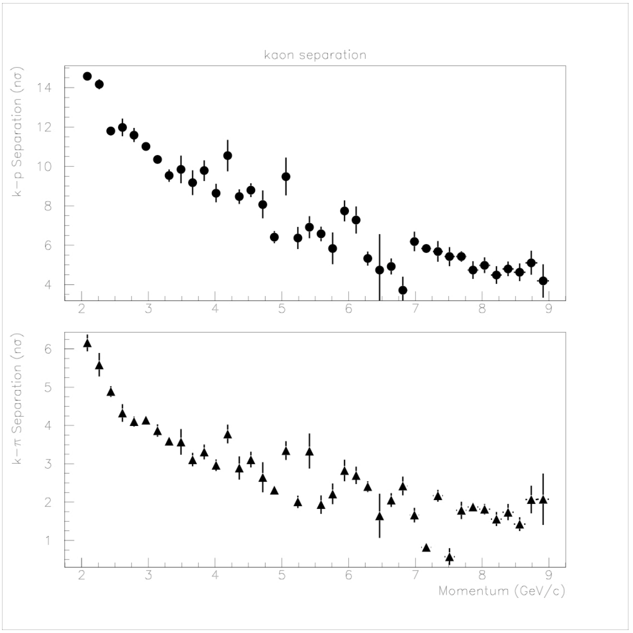
80_2



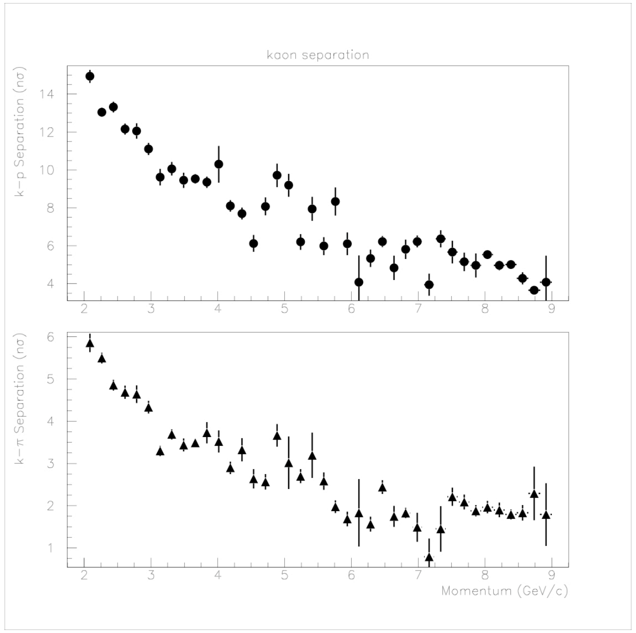
80_2.5



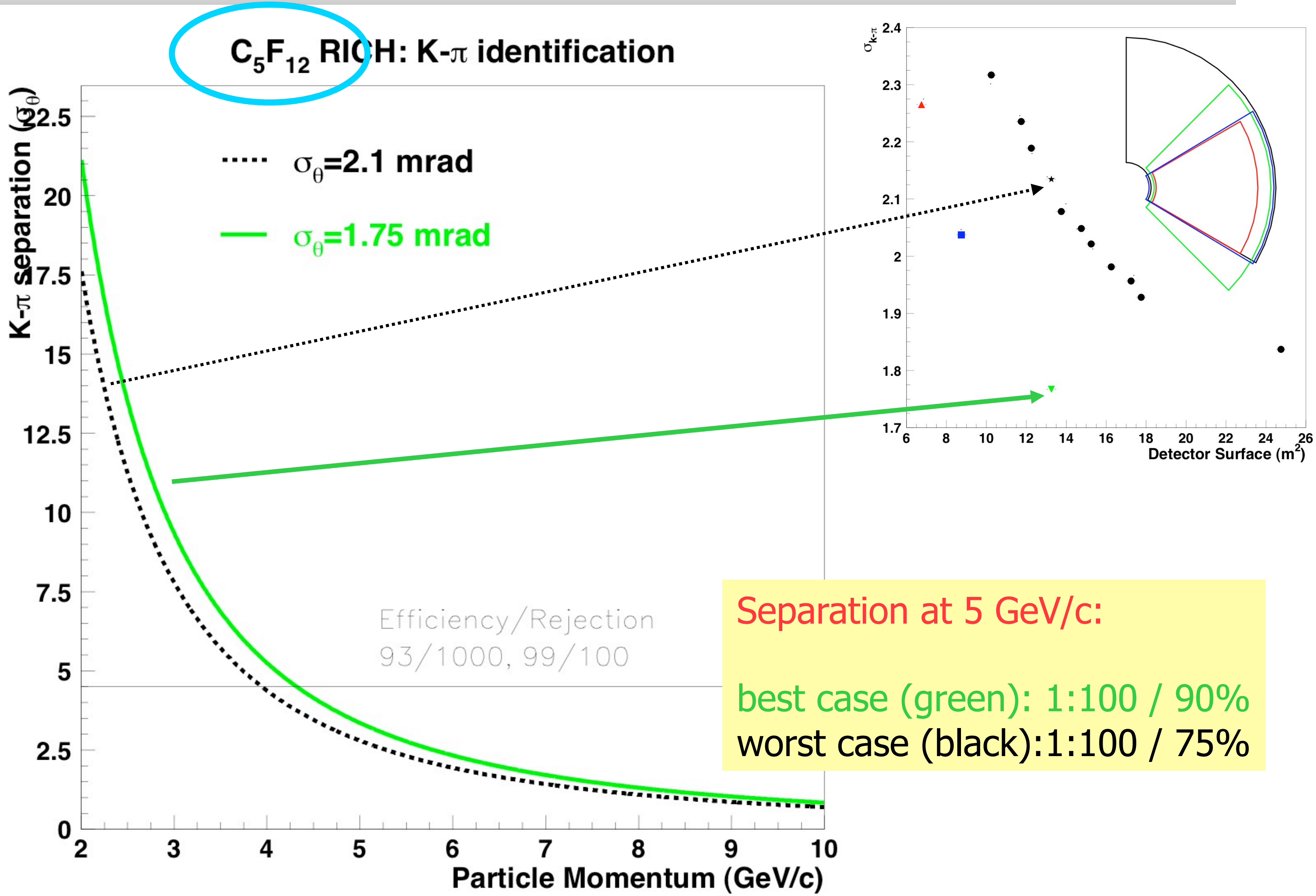
80_3



80_3.5



K-π Separation



Separation at 5 GeV/c:

best case (green): 1:100 / 90%

worst case (black):1:100 / 75%