Proximity-focusing RICH for ATHENA electron endcap

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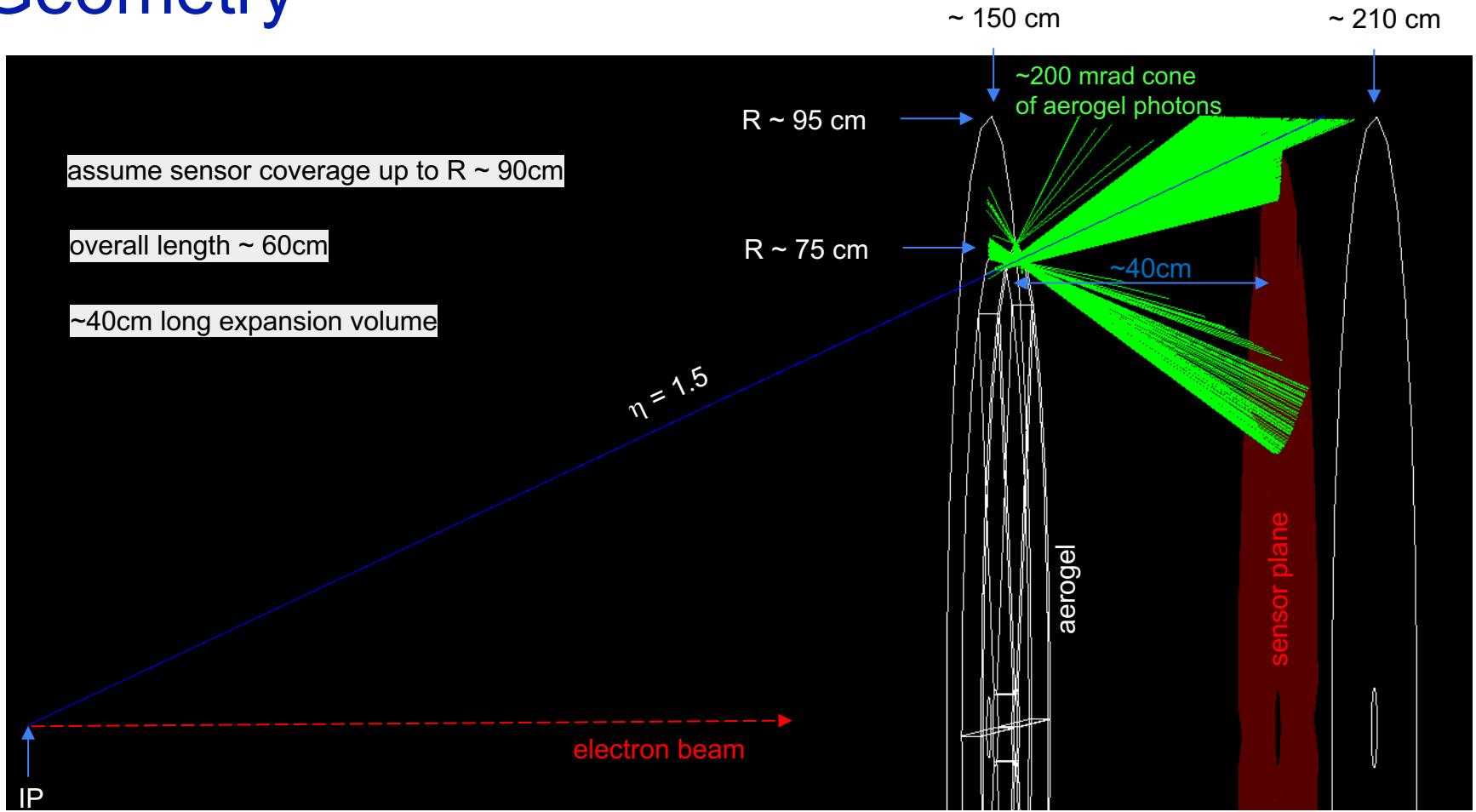
Objectives and setup details

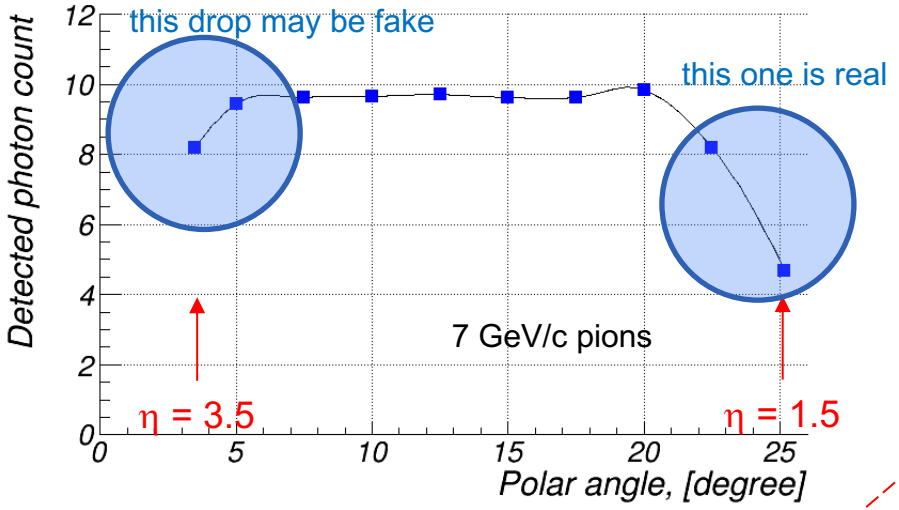
- Look for a “simple” complementary option to mRICH

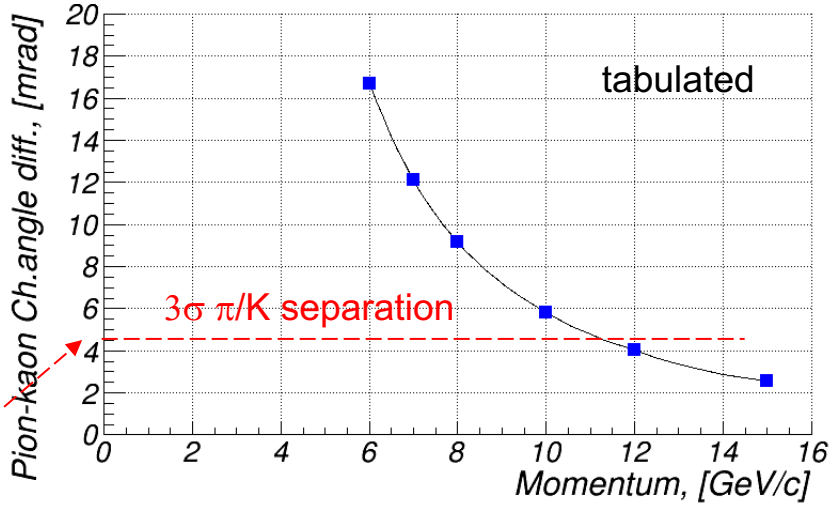
- Geometry: proximity focusing, no mirrors
  - Aerogel: model#3 (CLAS12 data), 3cm thick @ density 110mg/cm^3 (<n> ~ 1.02)
    - Rayleigh scattering, absorbtion
  - Acrylic: 3mm thick, “cutoff” set @ 350nm
  - ~40cm long air expansion volume (how about CF_4?)
  - SiPMs (S13361-3050AE-08 8x8 panels)
    - 3.4 mm pitch
    - QE as given by Hamamatsu
    - 85% geometric fill factor & 70% “safety factor” on top of it
- Same custom GEANT4 / ROOT software as used for dRICH evaluation

Geometry


~ 150 cm
~ 210 cm
~200 mrad cone
of aerogel photons
R ~ 95 cm
R ~ 75 cm
assume sensor coverage up to R ~ 90cm
overall length ~ 60cm
~40cm long expansion volume
~40cm
η = 1.5
aerogel
sensor plane
electron beam
IP

Some performance plots

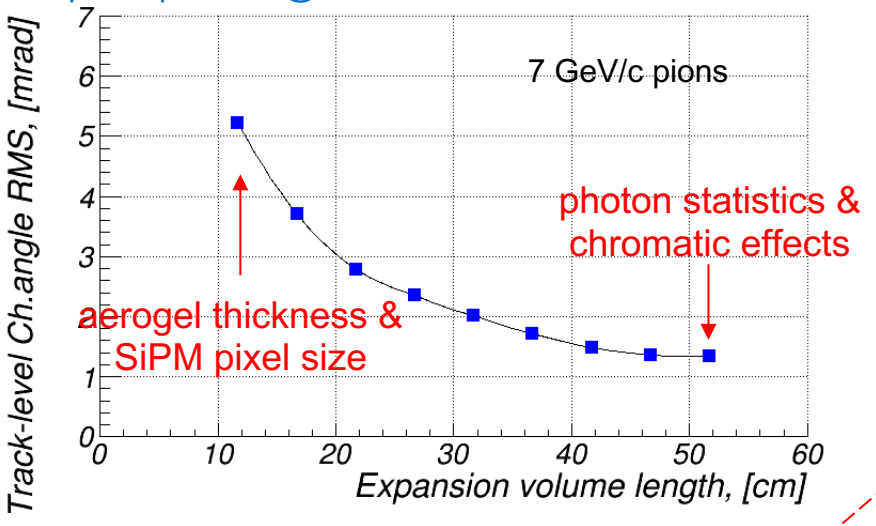


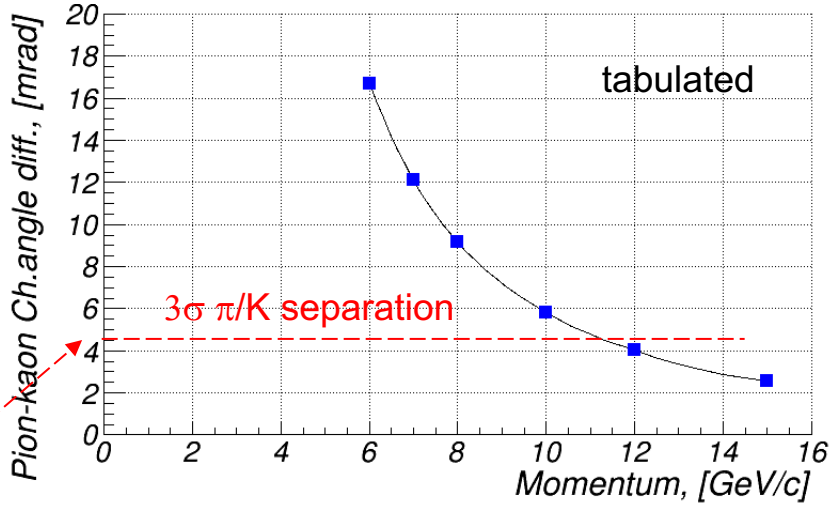


- ~10 p.e. per track and ~1.5 mrad track-level Cherenkov θ resolution
- Uniform response across the acceptance

Some performance plots

p/K separation @ 7 GeV/c for n ~ 1.02 is ~12 mrad





- ~10 p.e. per track and ~1.5 mrad track-level Cherenkov θ resolution
- Uniform response across the acceptance
- Configurations with mirrors do not seem to be practical if the goal is to cover the angular acceptance all the way up to ~25^0

Back of the envelope calculations

- Basic numbers:
  - Consider a ~10 GeV/c particle hitting 3cm thick aerogel with <n> = 1.02 at ~90^0
  - Take expansion volume ~400 mm away and 3.4 mm pitch SiPMs
  - Saturated Cherenkov angle for this <n> is ~200 mrad, and we know n_γ~10 makes sense
- Emission point contribution:
  - $\sigma_\theta \sim$ (30mm * 0.2 / $\sqrt{12}$) / 400 mm -> 4.3 mrad
- Pixel size contribution:
  - $\sigma_\theta \sim$ (3.4mm / $\sqrt{12}$) / 400 mm -> 2.5 mrad
- Chromatic distortion:
  - As a matter of fact, $\sigma_n \sim$ 0.00034 for the detected λ range, and $d\theta/dn$ ~ 5mrad / 0.001
  - $\sigma_\theta \sim \sigma_n * d\theta/dn$ = 0.00034 * 5mrad / 0.001 -> 1.7 mrad
- All together in quadrature and times $1/\sqrt{n_\gamma}$: ~1.65 mrad
  - [makes sense, compare to ~1.5 mrad from the GEANT -> IRT pass as a final fit result]

What is missing in the simulation?

Not much

- Aerogel bulk volume refractive index variation (aka forward scattering effect):
  - NIM A876 (2017) 168 [CLAS12 R&D]: σ_θ < 1 mrad for n = 1.05 and 3 cm thick aerogel
  - NIM A556 (2006) 140 [LHCb R&D]: σ_θ ~ 0.9 mrad for n = 1.03 and 5 cm thick aerogel
- Non-flatness of the aerogel-air boundary:
  - NIM A876 (2017) 168 [same CLAS12 paper]: one should be able to maintain the distortions at a level of σ_θ < 1mrad even for n = 1.05 aerogel (n = 1.02 case would be ~2.5 times more relaxed with the same surface quality)

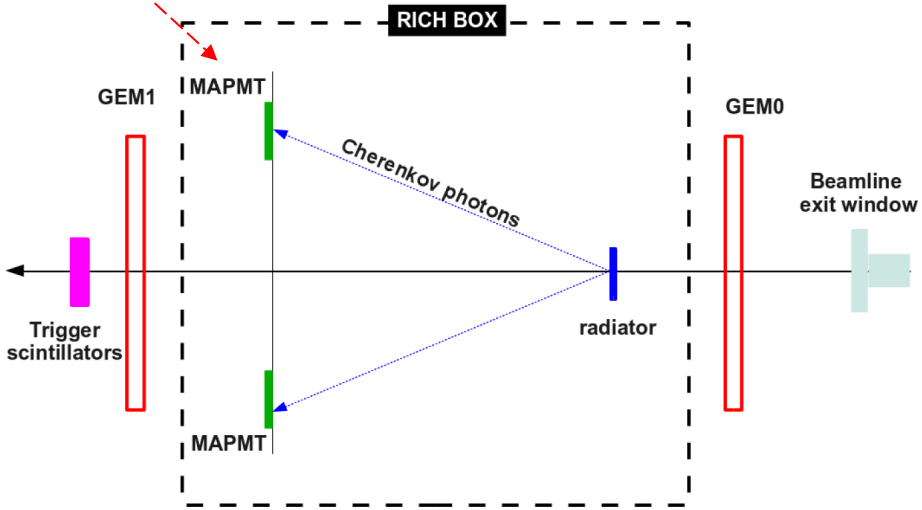
-> compare to ~4.5 mrad single photon Cherenkov angle resolution estimate following from the GEANT -> IRT pass

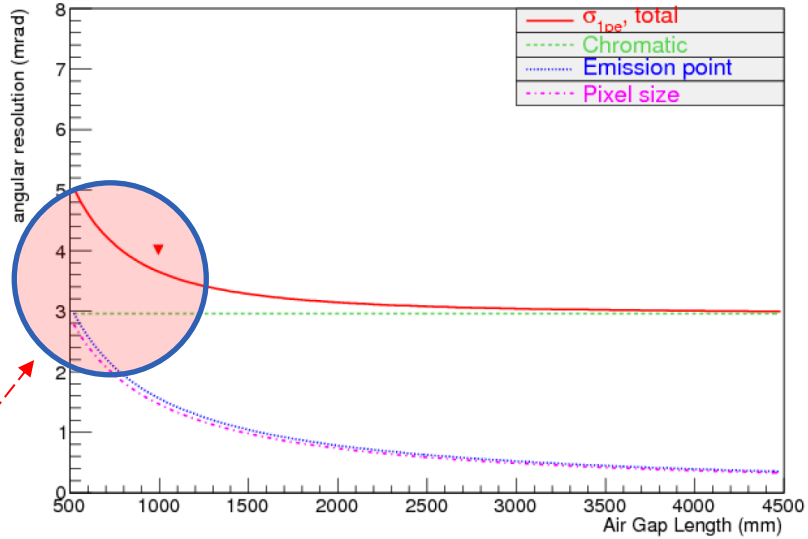
- Anything else?

CLAS12 prototype test

EPJ A52 (2016) 23: 4σ π/K separation at 8 GeV/c

~6mm pixel size





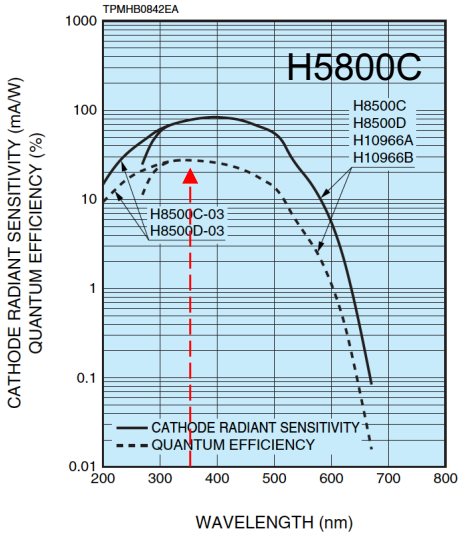
dominated by chromatic effects

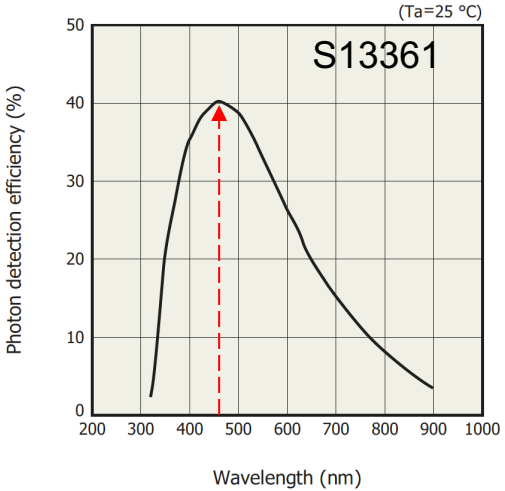
- The geometry:
  - 2cm thick aerogel with n ~ 1.05
  - Expansion volume ~1 m

Yet single photon angle RMS ~ 4.5 mrad. Why?

CLAS12 prototype test

- Not all photons are “equally good”
  - H5800C MaPMT has a peak of QE ~ 350nm
  - S13361 SiPM QE peaks at >450nm





$\sigma_\theta \sim 3.0$ mrad Chromatic effect $\sigma_\theta \sim 1.7$ mrad

Larger emission point uncertainty