RICH12 Update: Simulations

- Material Properties
- 1 p.e. Resolution
- $N_{p.e.}$ Counting

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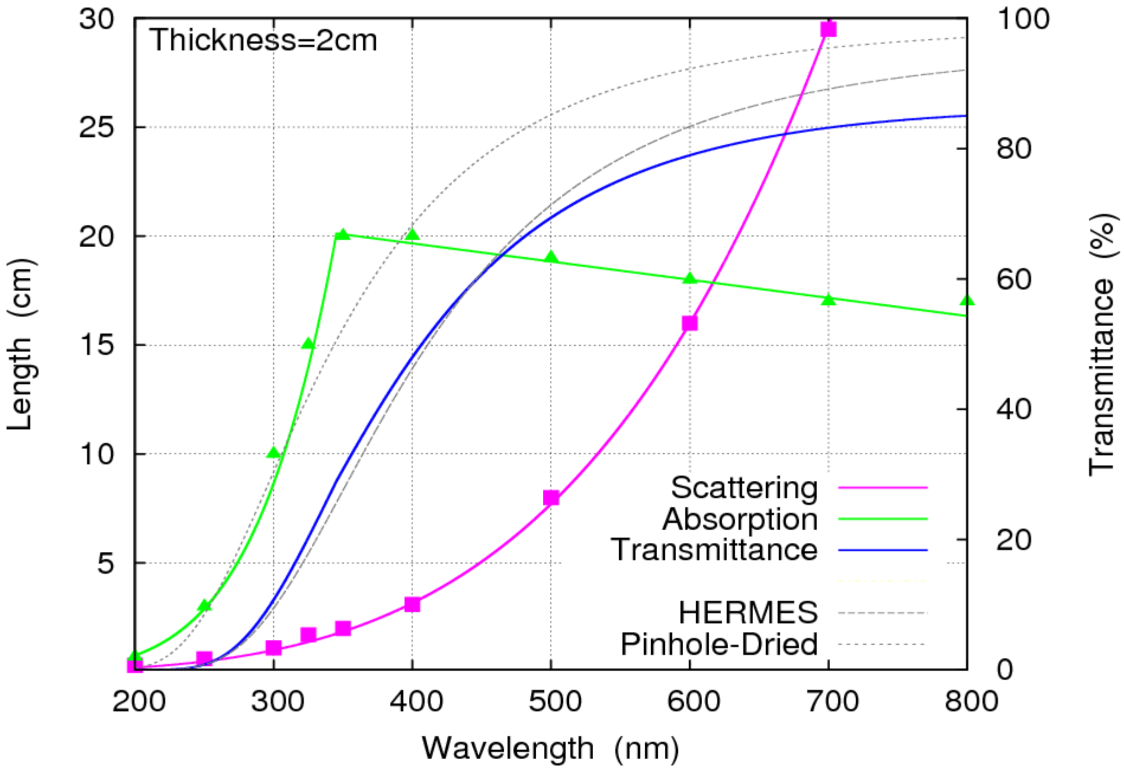
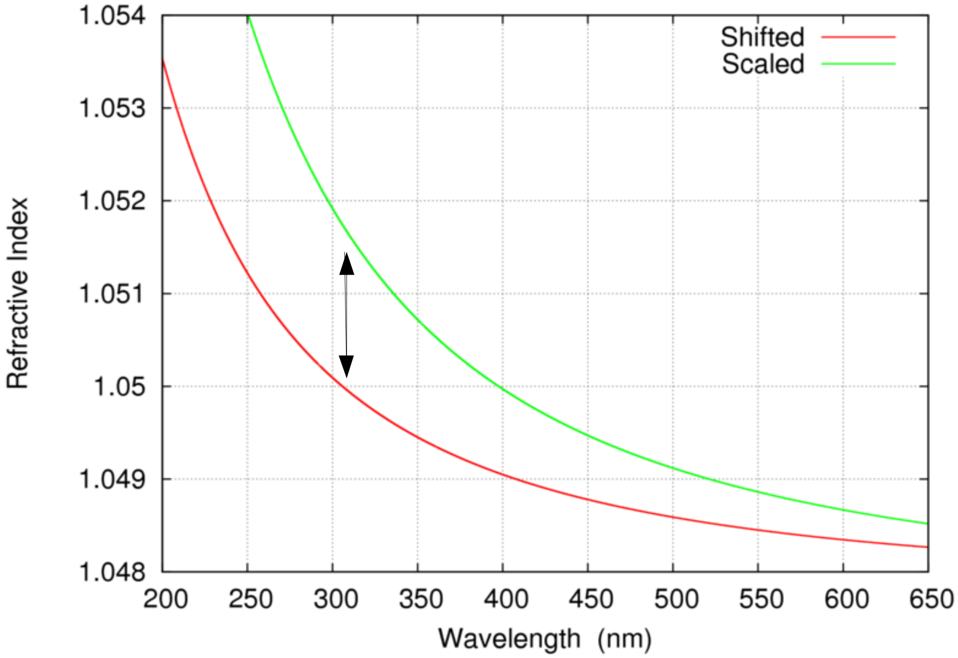
Aerogel Scattering & Absorption Lengths

- GEANT4 allows for absorption and Rayleigh scattering lengths.
- Previous RICH12 simulations treated scattering as absorption (and assumed P-D transmittance): $$\frac{1}{\Lambda_{A_{eff}}} = \frac{1}{\Lambda_A} + \frac{1}{\Lambda_S}$$
- Only 1 Aerogel measurement (HERMES): *Aschenauer et.al, NIM A 440 (2000) p338*
  - Estimate Scattering and Absorption lengths from their figures and calculate corresponding Transmittance just for comparison.



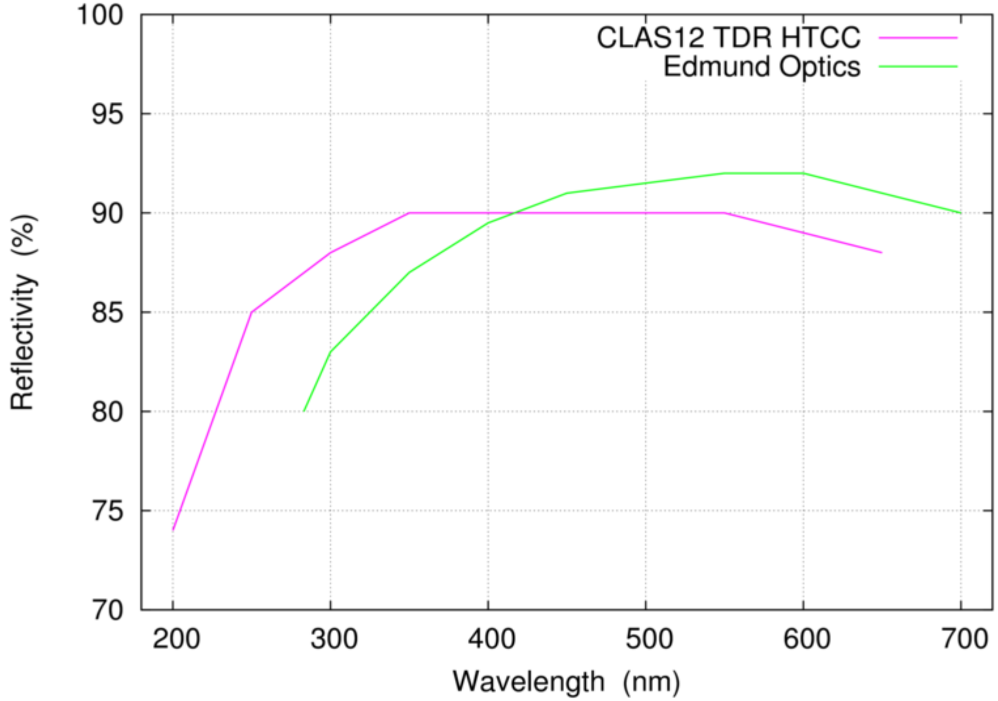
Aerogel Dispersion

- Chromatic dispersion of Aerogel has only been measured for refractive index of 1.03, for example: *Bellunato et al, EPJ 52 (2007) p183*
- Previous RICH12 simulations emulated other refractive indices by shifting $n_{1.03}(\lambda)$ dispersion: $n(\lambda) = n_{1.03}(\lambda)+k$
- Marco C. made a better estimate by scaling: $n(\lambda)-1 \propto n_{1.03}(\lambda)-1$
- By simulating this dispersion, accounting for all transmittances and detetection efficiencies, the result is a 50% increase in σ_n.



Mirror Reflectivity

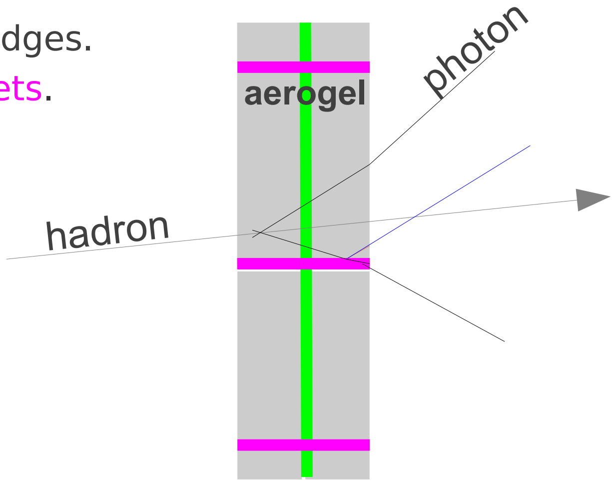
- Previous RICH12 simulations assumed flat efficiency. (90 or 100%)
- Two examples of reflectivity for aluminum with protective MgF_2.
- We are now using the HTCC mirror reflectivity from CLAS12 TDR.
- For simplicity we use G4SkinSurface, which makes every surface of the mirror volume reflective. Once geometry is finalized, best to use G4BorderSurface.



Optical Surfaces

Next step to bring simulation closer to reality.

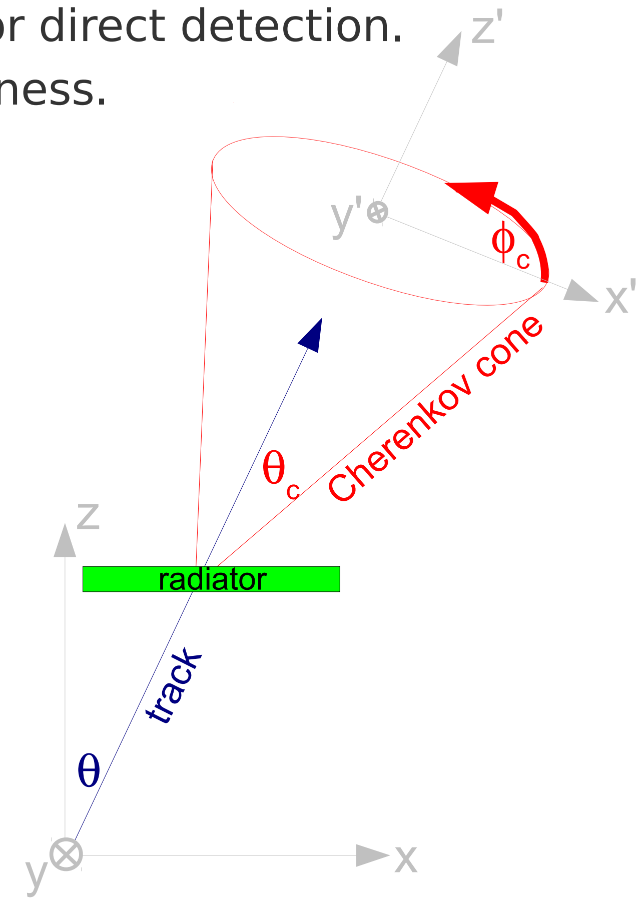
- Mirror (and Aerogel) Surface Roughness
  - GEANT has surface roughness parameter α that smears the normal.
  - HERMES utilized its mirror's α as an overall tuning factor to match the simulated resolution to their real data.
  - But RICH12 has direct and reflected photons.
- Aerogel Tiling
  - Transverse interfaces should be small effect.
  - But longitudinal interfaces are more significant.
    - Production method causes resolution issues at tile edges.
    - HERMES dealt with this using absorptive Tedlar sheets.
    - Also issue of internal reflection.
- How to Proceed?



Theoretical Resolution

Ypsilantis et al, NIM A 343 p30 (1994)

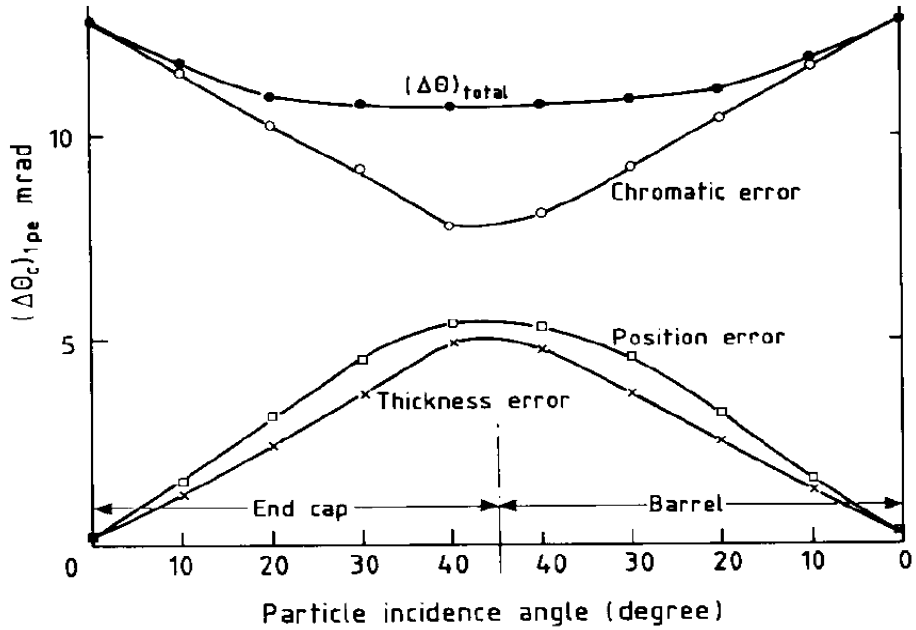
- Full calculation for skewed tracks, while the simple and more commonly seen equations are for normal tracks only.
- Includes all effects presently in the simulation for direct detection.
  - Should diverge after including surface roughness.
- Input parameters:
  - Radiator geometry and dispersion.
  - Photon detector spatial resolution.
  - Proximity gap length.
- Output:
  - Resolution as function of:
    - θ – Incident angle
    - ϕ_c – Cherenkov Cone Azimuth
- Must exhibit expected symmetries



Testing the Theoretical Resolution

Ypsilantis et al, NIM A 343 p30 (1994)

- One published, simulation resolution study showing incident angle dependence: *R. Arnold et al., NIM A 273 p466 (1988)*
- Very sensitive scenario with short gap, NaF radiator (n~1.32)
- Provides opportunity to compare with theory.

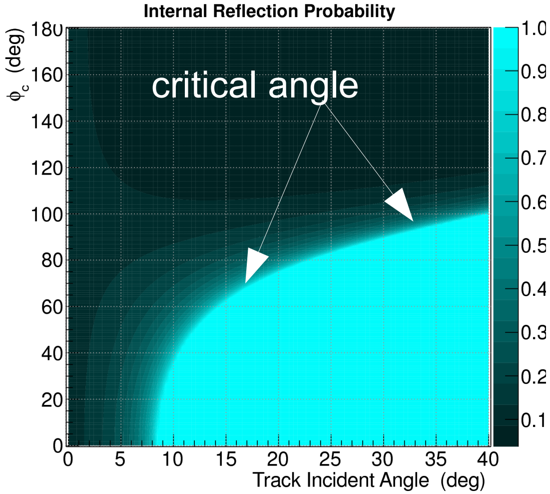


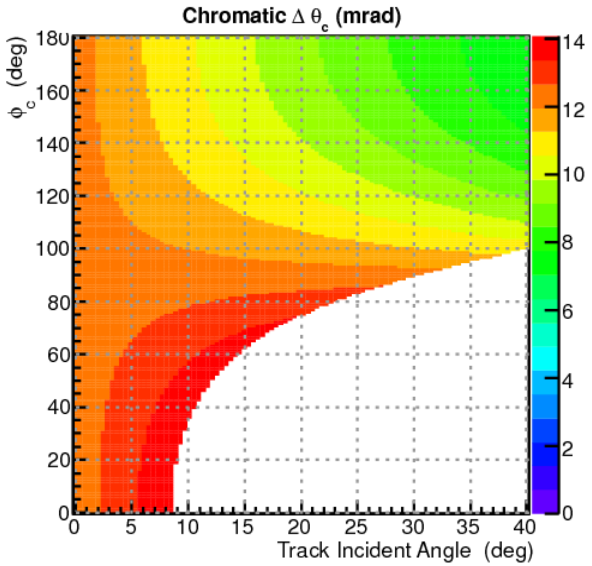
- Get geometry, material, detector parameters from paper, and
- Calculate theoretical resolution contributions function of θ and ϕ_c:

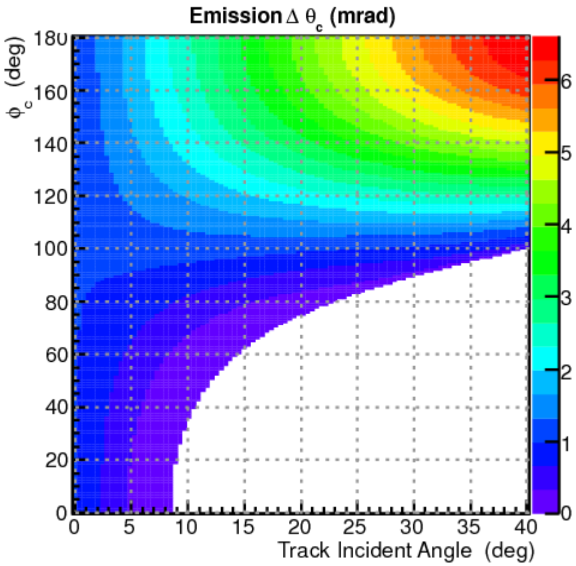
Testing the Theoretical Resolution

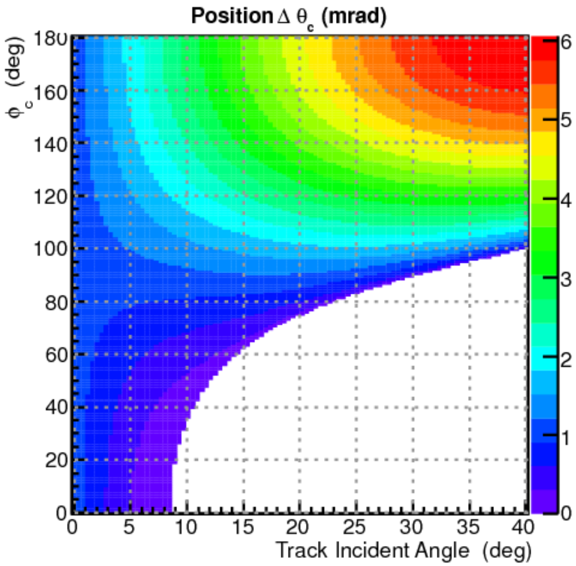
Ypsilantis et al, NIM A 343 p30 (1994) implemented for R. Arnold et al., NIM A 273 p466 (1998)

- Strong resolution variations.
- Constricted range due to internal reflection because n=1.32!
- To compare with simulation, average over ϕ_c, accounting for tranmission probability.



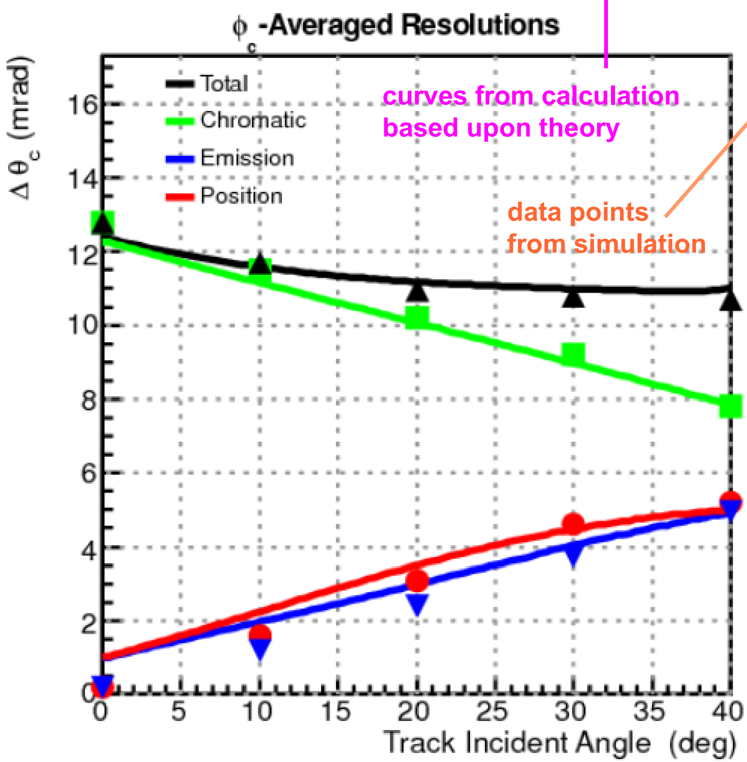


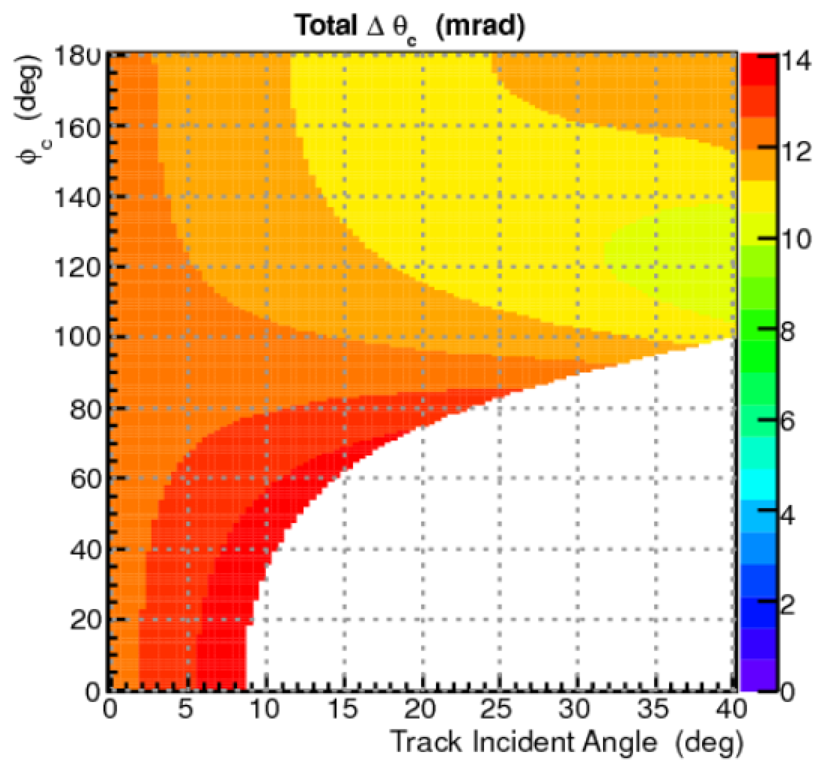




Testing the Theoretical Resolution

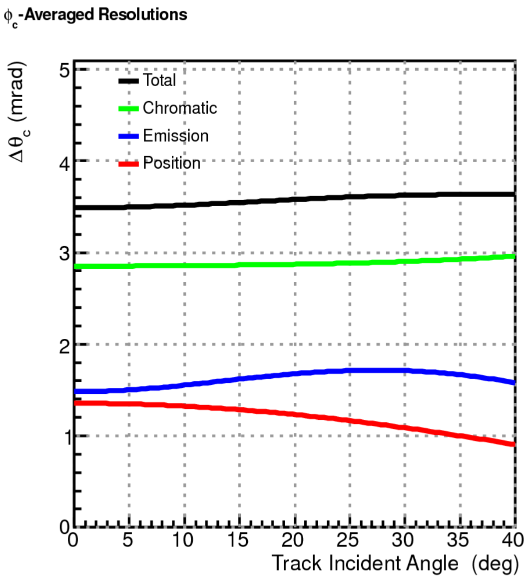
Ypsilantis et al, NIM A 343 p30 (1994) *VS* *R. Arnold et al., NIM A 273 p466 (1988)*

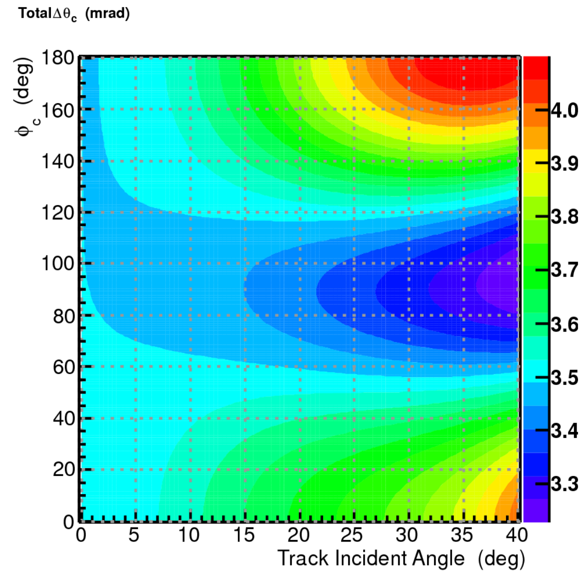




Excellent Agreement

Theoretical Resolution for RICH12

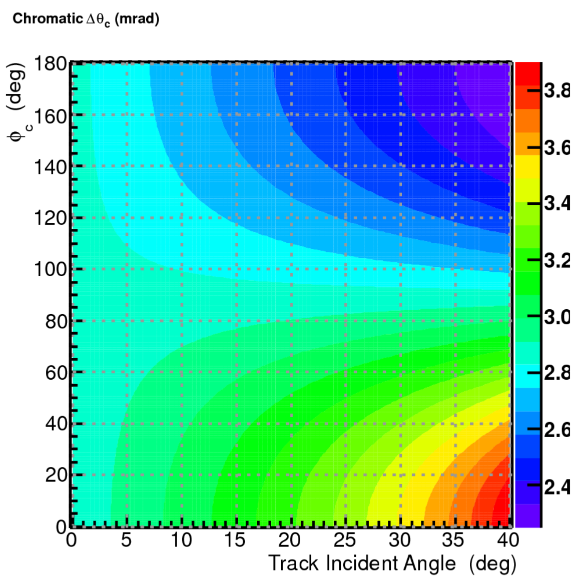


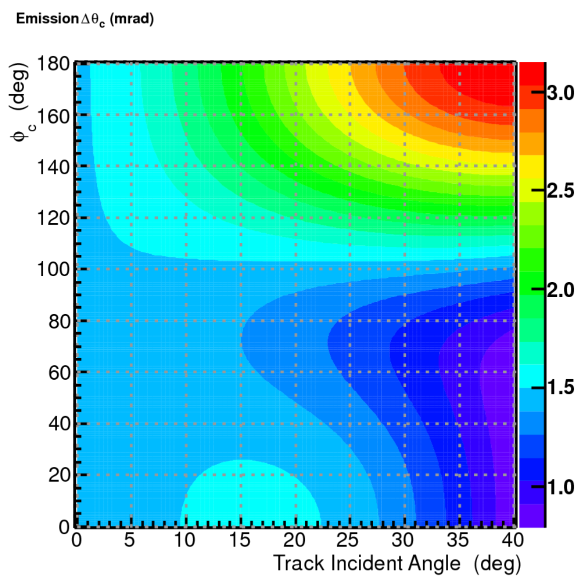


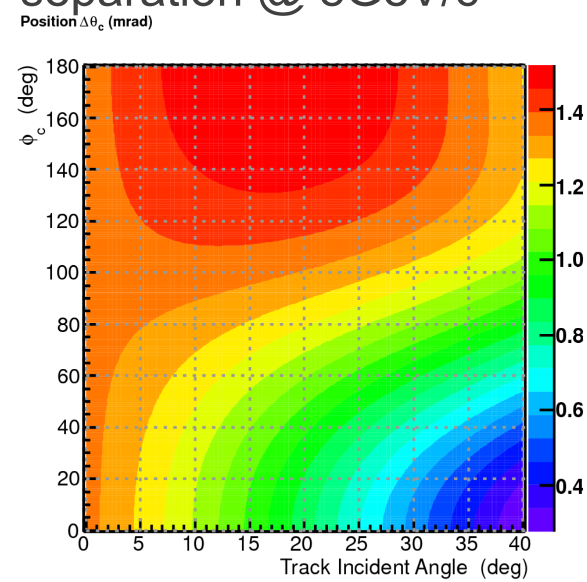
Index of Refraction = 1.05
Radiator Thickness = 20.0 mm
Gap Length = 105.0 cm
Pixel Size = 5.8 mm
σ_n = 8.7e-04

Small Variation in Cherenkov angle resolution

4mrad resolution requires 8 p.e. for 4-σ π/K separation @ 8GeV/c







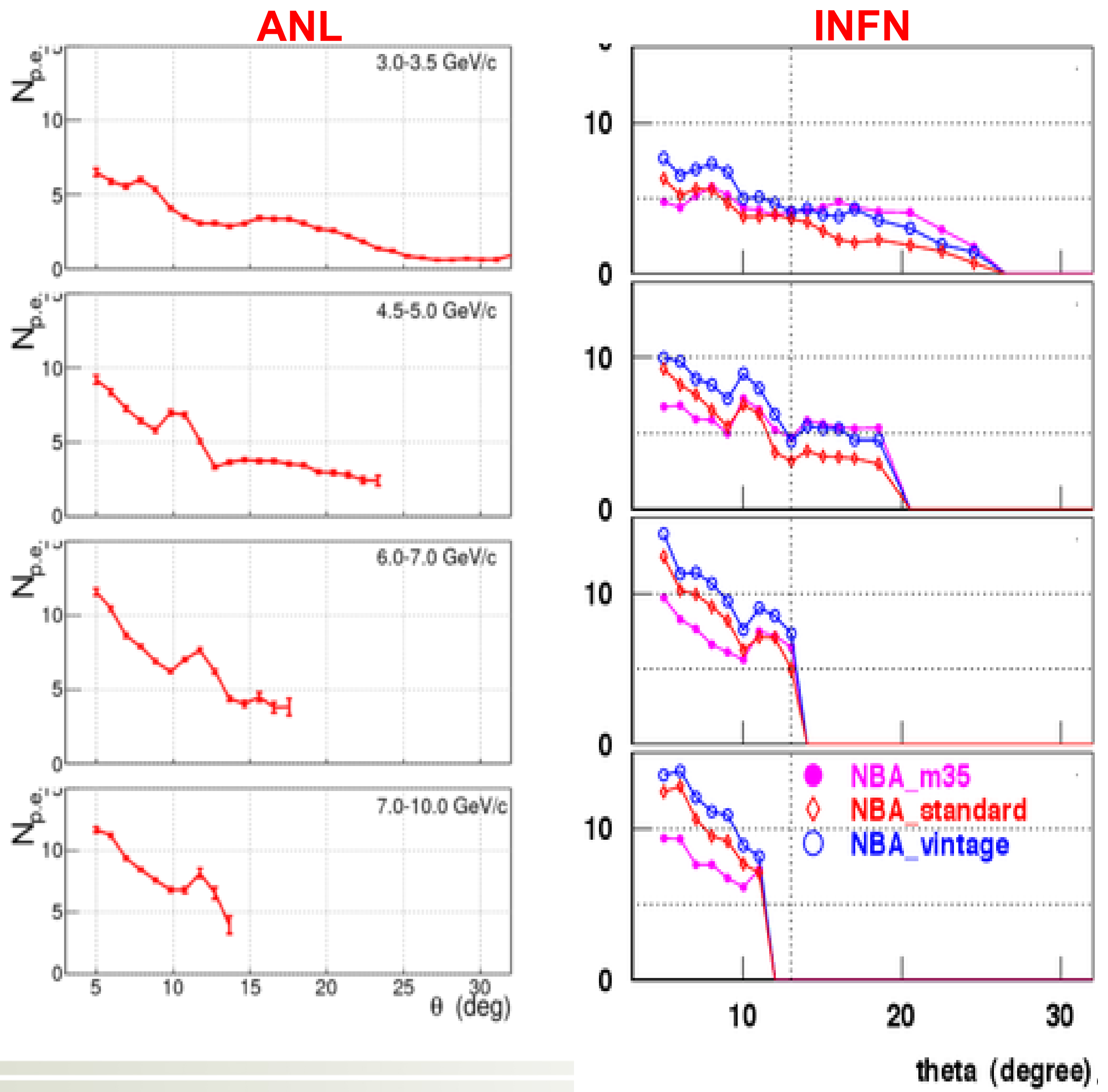
Simulated $N_{p.e.}$ Counting

- Cross-check with “frozen” GEMC simulation
  - Geometry: 2-4-6-8-10 radiator, 25° coverage
  - Materials: n=1.05, HTCC reflectivity,
  - H8500-NBA QE and Pixellization
  - RICHhitprocess

  - 65% global efficiency – fudge factor
  - Cross-sector allowed
  - Same binning for comparison

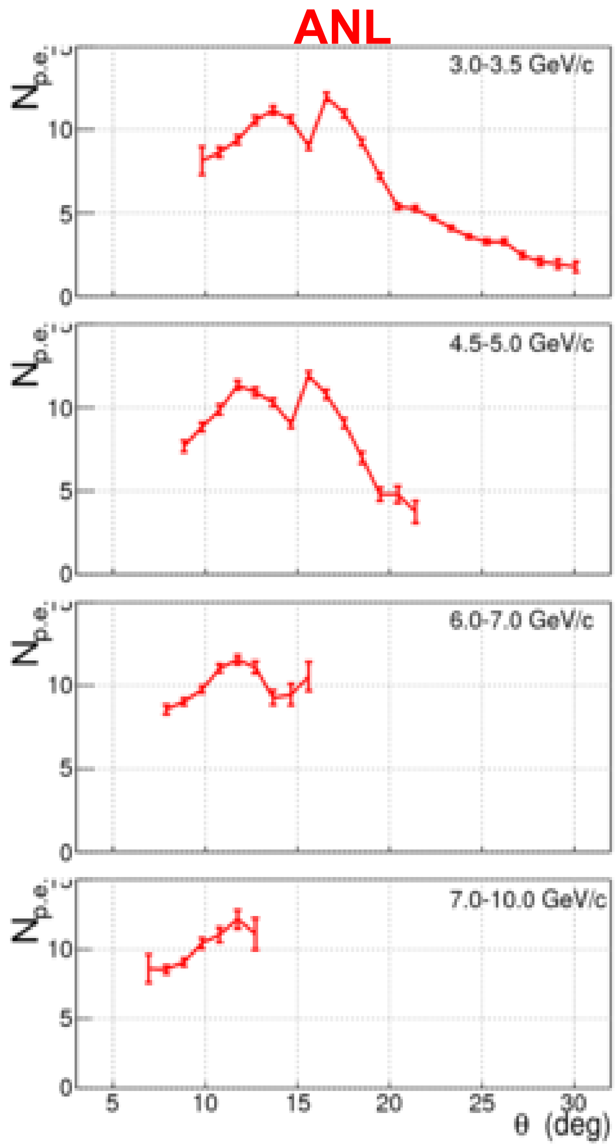
Simulated $N_{p.e.}$ Counting: π^+

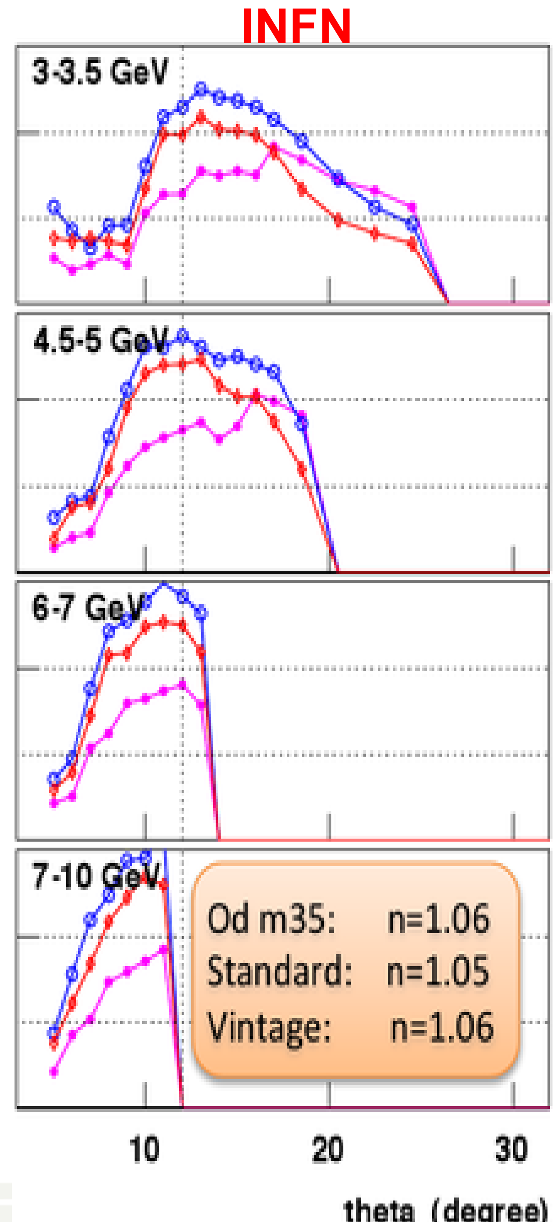
- Compare red points
- ANL extends to larger θ due to larger statistics
- Good agreement



Simulated $N_{p.e.}$ Counting: π^-

- Compare red points
- ANL points cut off at small θ due to fiducial cut, and extend to larger θ due to larger statistics
- Good agreement





Summary & Outlook

- Material properties are more realistic in simulation, further refinement will require measurement.
- Next simulation improvement is surface roughnesses. (mirrors and aerogel)
- $N_{p.e.}$ cross-check gives good agreement.
- Theoretical resolution calculation has been verified against published simulation with a sensitive geometry and materials.
- Resolution shows small dependence on trajaectory for RICH12.
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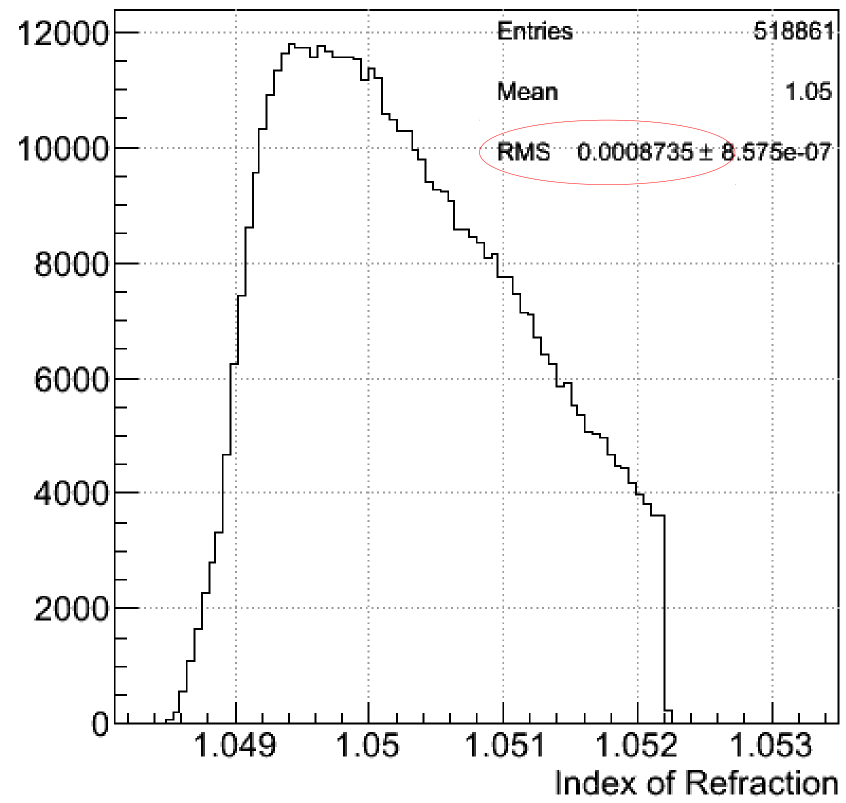
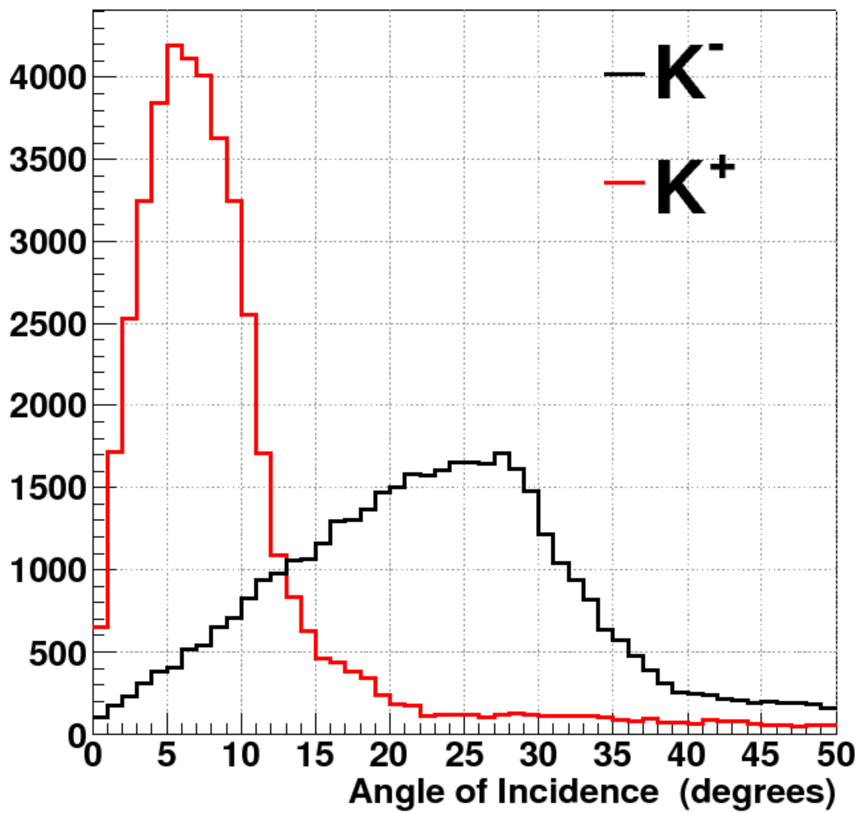
Simulated Spread in Refractive Index

- 50% increase in σ_n due to proper scaling of dispersion relation for different (unmeasured) refractive indices.



Simulated Incident Angles

- Incident angle differs due to magnetic field bending.



Cherenkov and Critical Angles