The influence of gas refractive index to the RICH detector accuracy

Miroslav Sulc Technical University of Liberec, Czech Republic

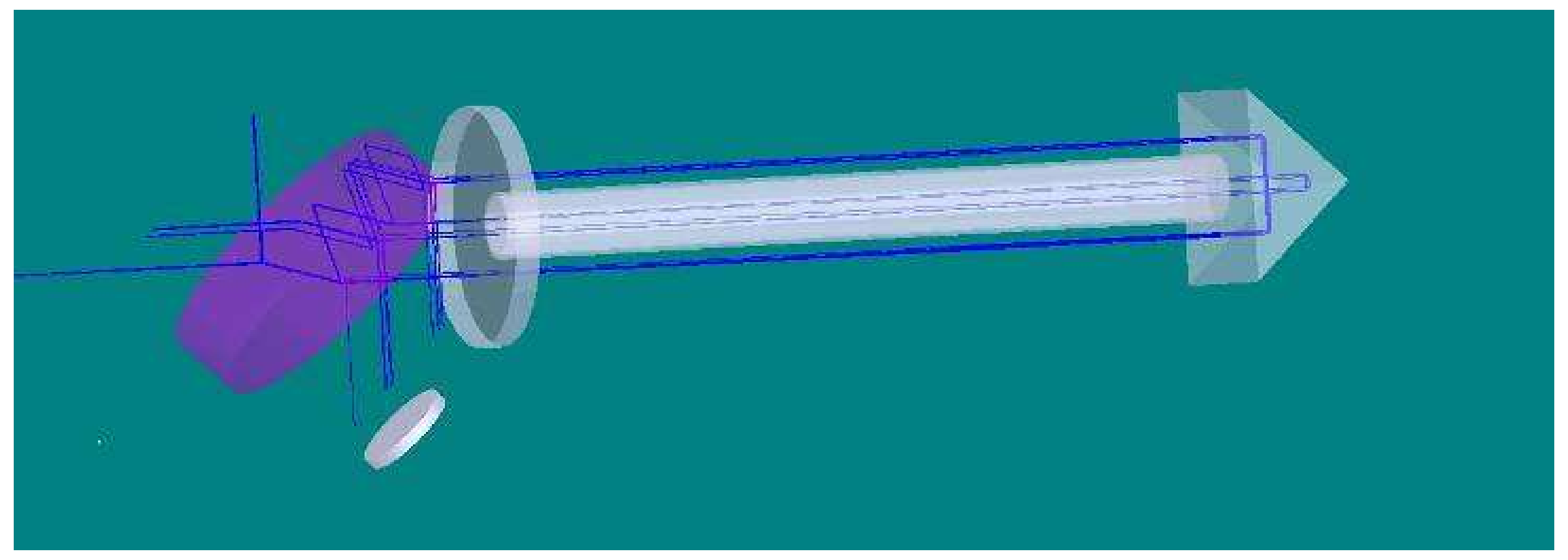
The refractive index *n* of radiator gas varies with gas density ρ in time as function of temperature *T*, pressure *p* and gas purity *c*. Gladstone-Dale equation is valid for gases

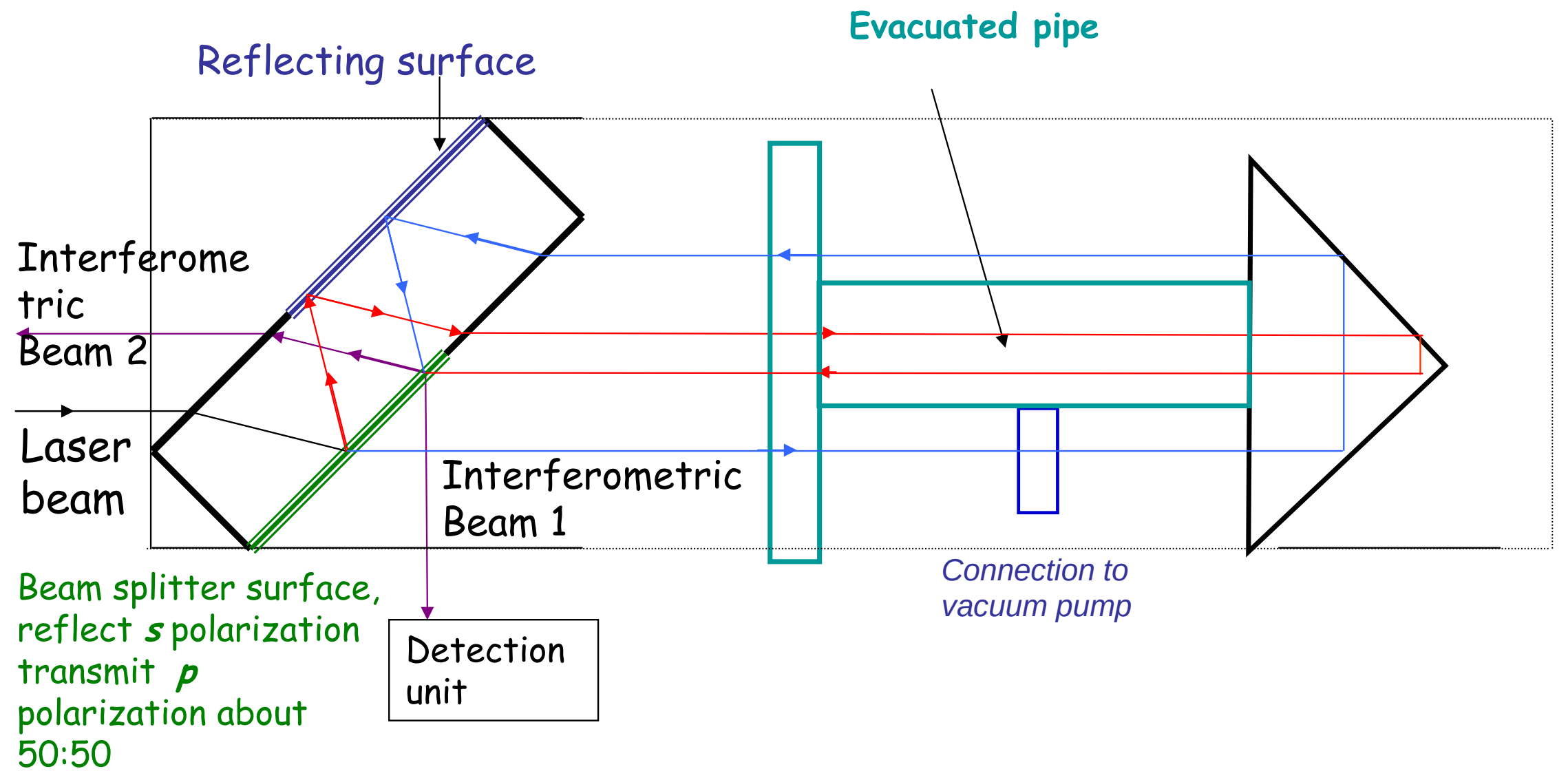
$$n(\lambda, p, T, c) - 1 = K(\lambda) \cdot \rho(p, T, c)$$

On-line monitoring of *n* for one wavelength gives information about change of *n* for all useful wavelengths of Cherenkov spectra.

The modified Jamin's Interferometer

The modified folded Jamin interferometer is insensitive to rotation and translation of its two optical elements. It is relatively a simple and vibration-insensitive interferometer. An incoming He-Ne laser beam (633 nm) is split by a polarization sensitive partial beam-splitter coating on the second surface of a plane-parallel plate. One of the resulting beams is reflected by a high-reflectance coating on the first surface. Two parallel beams of equal intensity with orthogonal polarization are generated by an appropriate beam-splitter coating. The first one is passing thru evacuated closed quartz pipe; the second one is passing outside this pipe. Both beams are reflected by retroreflected prism. Both are passing true the same quartz disk on the end of pipe so the phase difference between beams is induced by refractive index difference only, not by thermal dilatation and so on.





Beams are joined together and reflected by additional mirror to the special detector unit. It divides the signal to two detectors placed behind analyzers (rotated by +45° and -45° with respect to the first beam polarization). The two signals with exact π/2 shift are measured. It enables to measure not only passing interferometric fringes but also direction of movement and phase difference smaller than 2π (quadrature encode measurement).

Interferometer is placed inside stainless steel chamber. It will be parallel connected with Compass RICH-1. The control of pressure and temperature inside chamber can confirm that there are the same conditions for gas as inside RICH vessel. On the start of the measurement the pipe in interferometer is filled by C_4F_{10} gas. There is no difference between beam phases. The pipe is connected to vacuum pump and slowly evacuated. The fringes (about 1400) are moving over detectors. The absolute value of refractive index (with respect to the vacuum) is obtained now. Changes of phase difference caused by refractive index unstabilities are observed after this. Sensitivity of interferometer is excellent - one fringe (2π) corresponds to the change of 10^{-6} of refractive index. It can be still improved by factor 100. All experiment is driven. In the case of laser or vacuum unstabilty all process can be repeated. Electromagnetic valves driven by by PLC - SIEMENS SIMATIC S7-300 enable gas filling and evacuation of the pipe in interferometer.

Interferometer will be connected in parallel to the Compass RICH-1 vessel

The simulation of chromatic aberration – difference between MAPMT and CsI detectors.

The Compass RICH-1 uses both CsI detectors (150-210 nm) and MA-PMTs (200-650 nm). Chromaticity error is very important for both ones.. Two different effective refractive indexes n_{ef} for PID – 1.001528 for CsI and 1.001345 for MAPMTs are involved in PID algorithm.

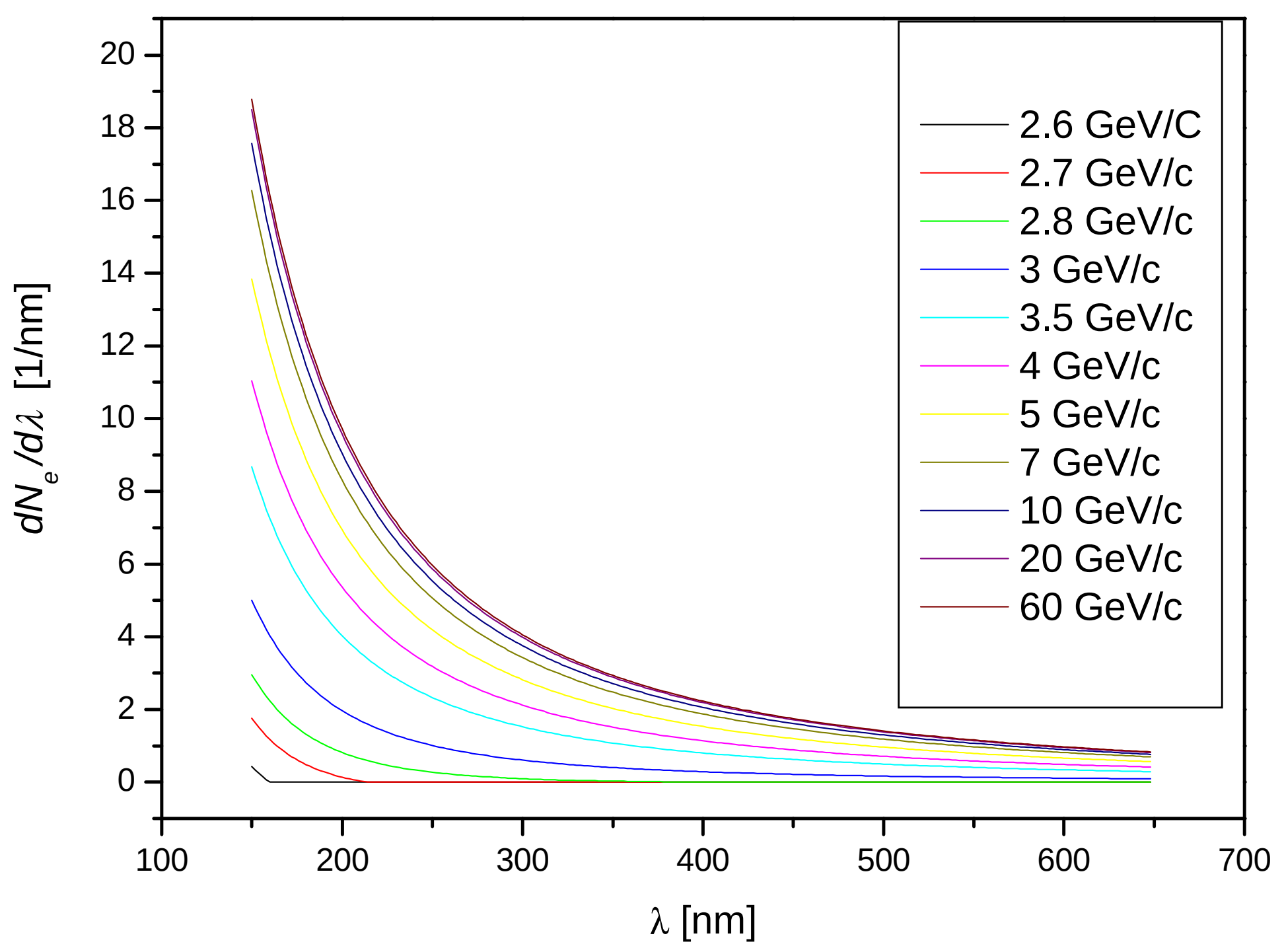
Simulation of chromaticity was made for different values of π^0 pion momentum taken as parameters. It concerns about only one particle, no statistics, no other errors were taken in account.

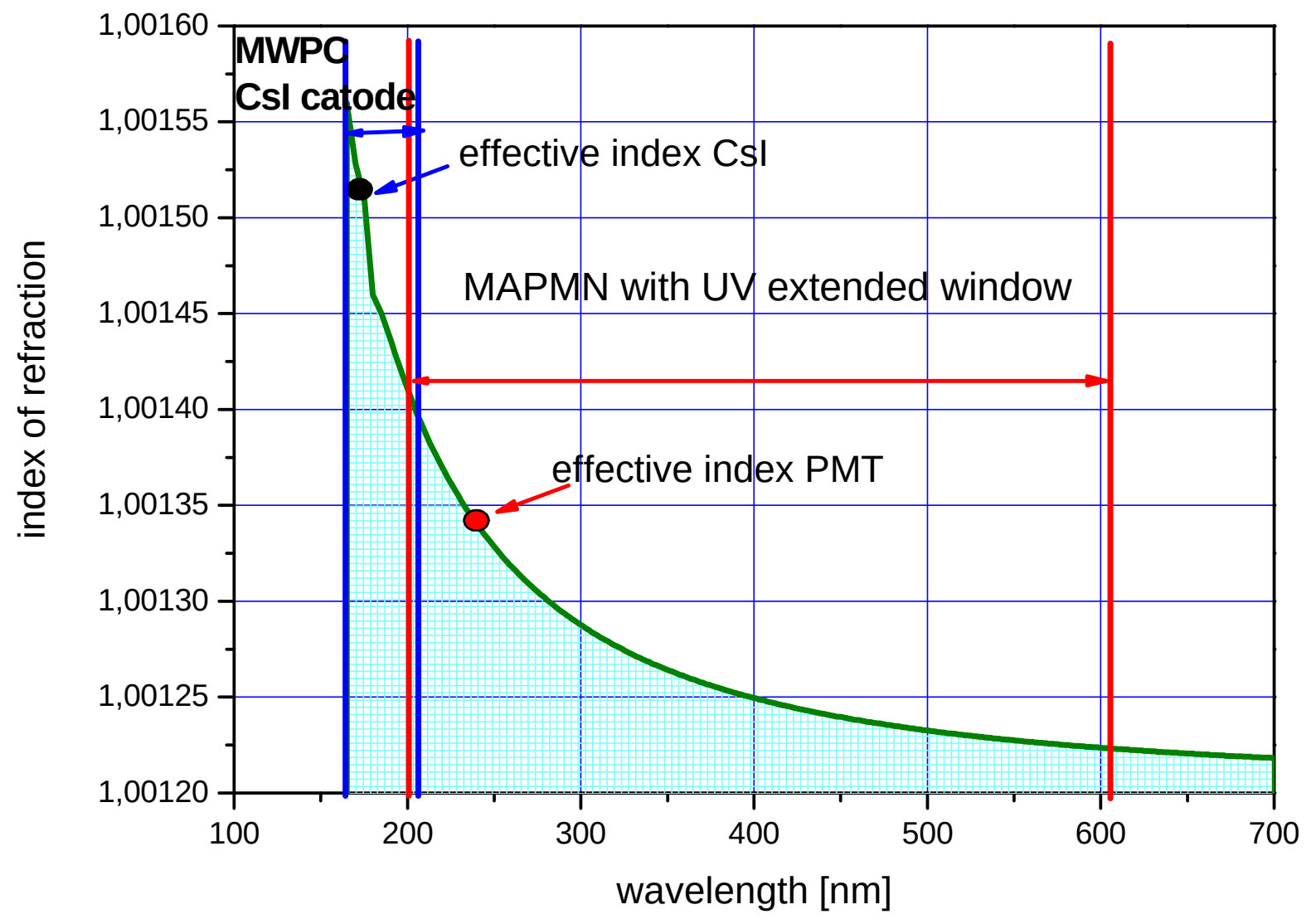
Number *dN* of detected photons per *dθ* was calculated from

$$\frac{dN}{d\theta} = \frac{dN}{d\lambda}\frac{d\lambda}{dn}\frac{dn}{d\theta}$$

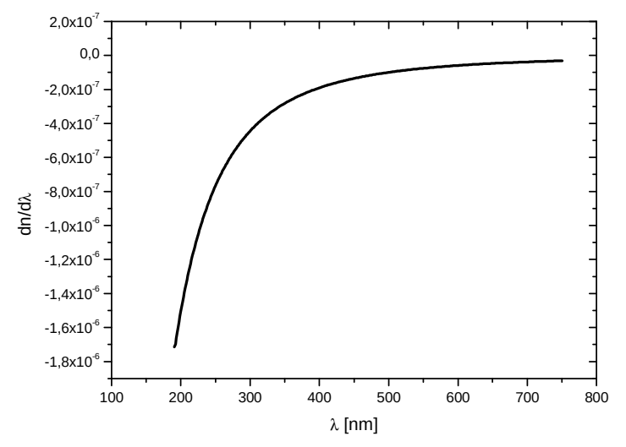
$$\frac{dN_e}{d\lambda} = \frac{2\pi\alpha}{\lambda^2} Z^2 L\left(1 - \frac{1}{n^2(\lambda)\cdot\beta^2}\right)$$, it depends on β in the case of momentum < 20 GeV/c

For momentum between cca 2.6 and 3 GeV/c Cherenkov photons are emitted only in UV range (where index of refraction is higher)

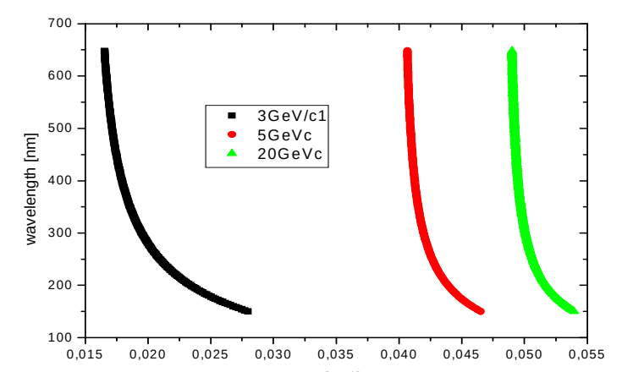




The accuracy of this simulation depends mostly on the measurement of dispersion curve $\frac{d\lambda}{dn} = \left(\frac{dn}{d\lambda}\right)^{-1}$ (from Albrecht E. and al., NIM A, 456 (2001), 190-205).



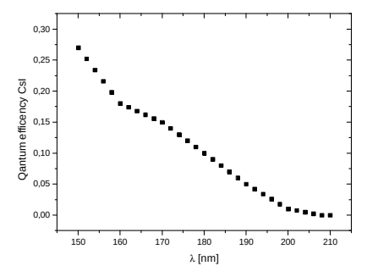
Photons emitted with wavelength from 400 to 600 nm "feel" very similar index of refraction so they appear in narrow angle *θ*. The wavelength of photons which can fall to the angle *θ* (for different *β*). It is calculated from $\cos\theta = 1/n(\lambda)\beta$. So for *p= 20 GeV/c* photons from range 300-650 nm can fall to very near angle. You can now estimate width of Cherenkov rings for different *β* from this figure. It is important to take in account that photons of different wavelength have a certain different probability to be detected. There are two opposite tendencies – photons from VIS can fall to near angle, but the number of detected ones is not so big. Photons from UV will be more spreaded and the number of UV photons is higher.



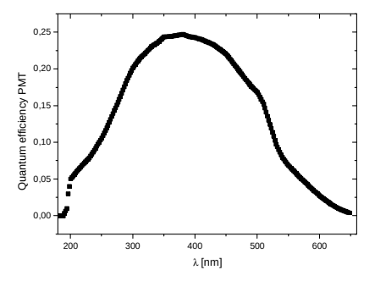
Number of detected Cherenkov photons is product of number of emitted Cherenkov photons and QE, T, R.

Quantum efficiency

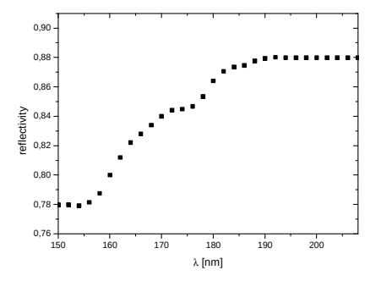
CsI



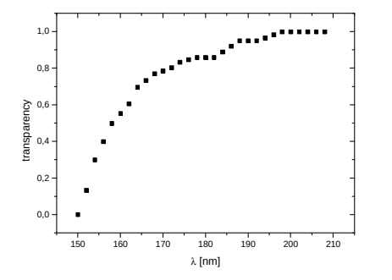
MAPMT

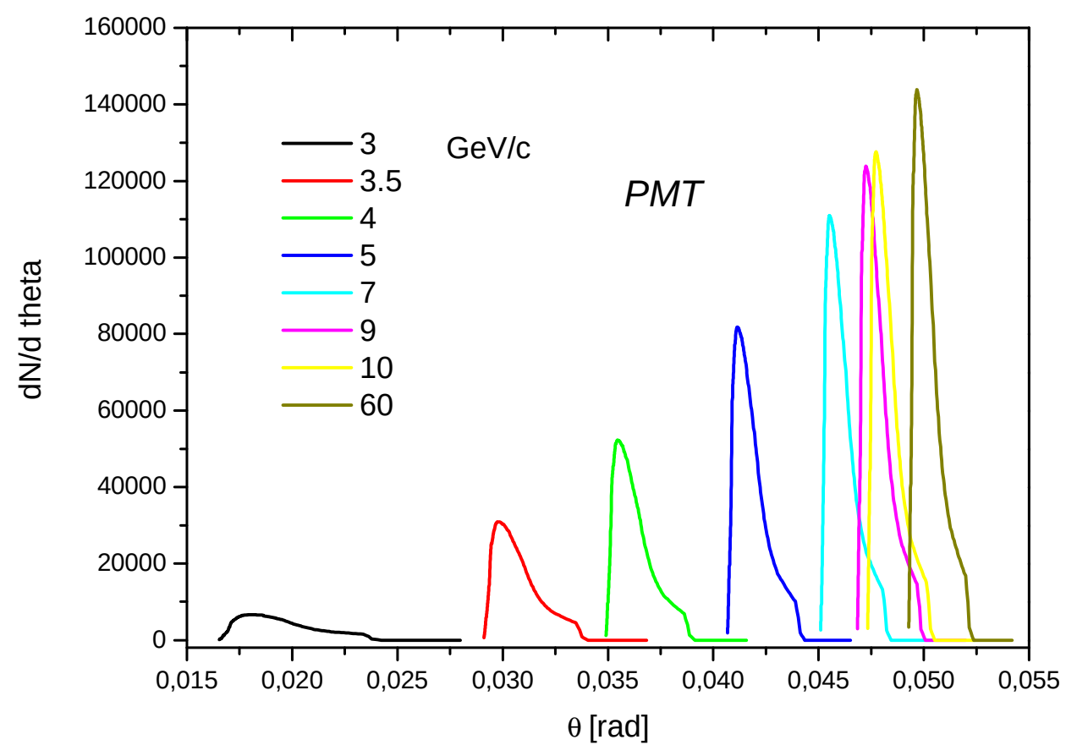


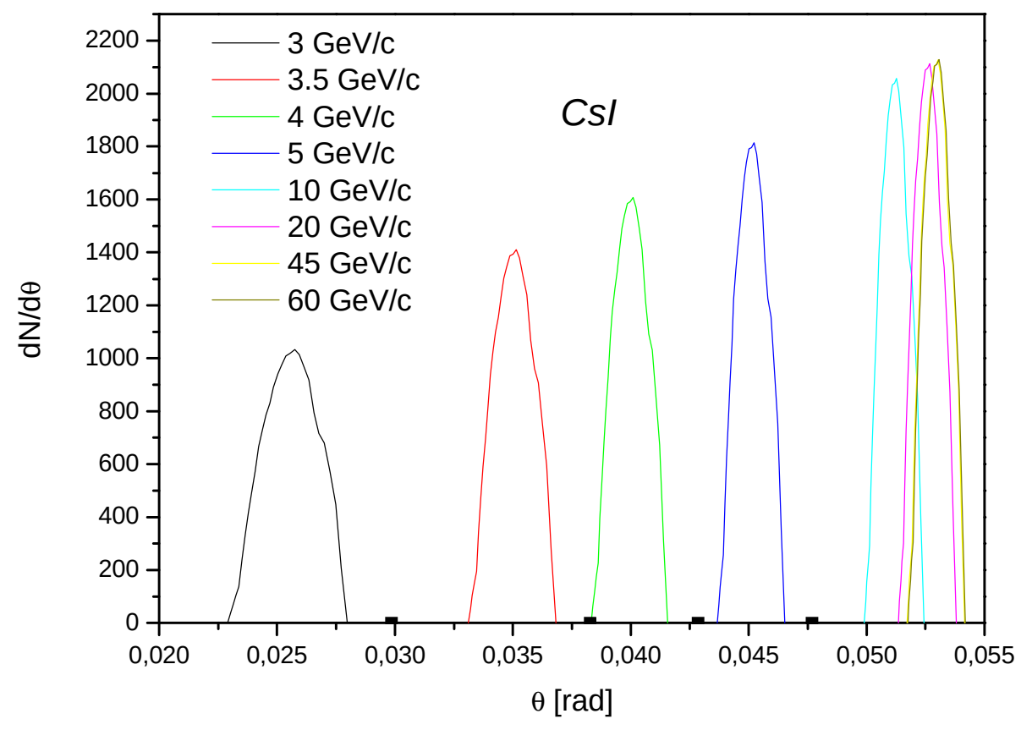
Mirrors reflectivity
Calculated as 0.9 for λ>200 nm,



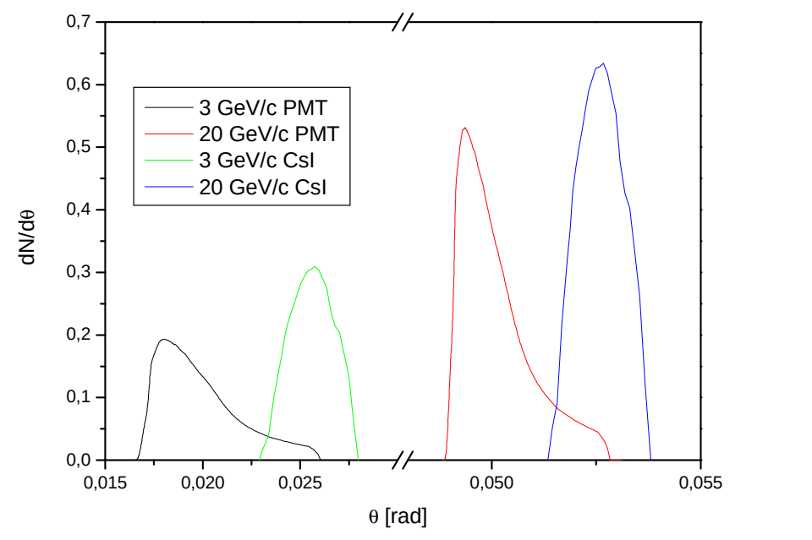
Transparency of C_4F_{10} gas
(and quartz telescopes
for MAPMTs)

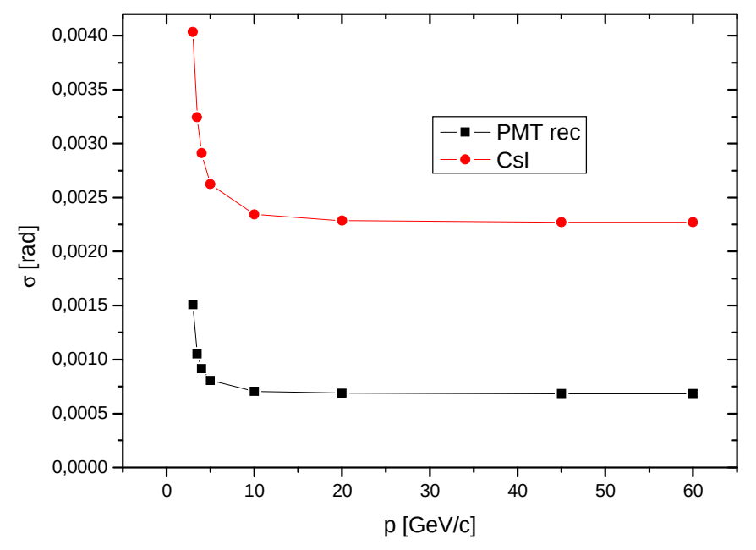






Simulation of angle distribution of detected photons *dN* per *dθ*, for different *π* momentum for PMTs gives results, that effective refractive index is depending on particle momentum especially for low momentum particles (for *π* at range 2.6-5 GeV/c). It can be implemented to PID identification algorithm.





The chromatic aberration has a influence also to width of the ring, or standard deviation of θring -θπ . For PMT we used recalculated rings with respect to CsI

From simulation results that effective index n is depending on momentum (for PMTs and small momentum particles) and is higher than this one used for calculation. *It can be implemented do PID algorithm.*

RICH2010, 3-7 May 2010, Cassis, France