XCET user requirements

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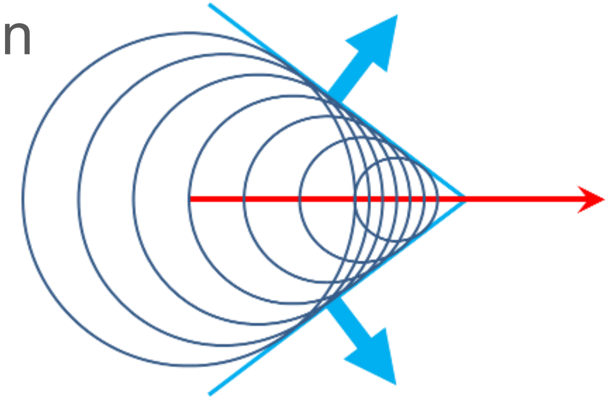
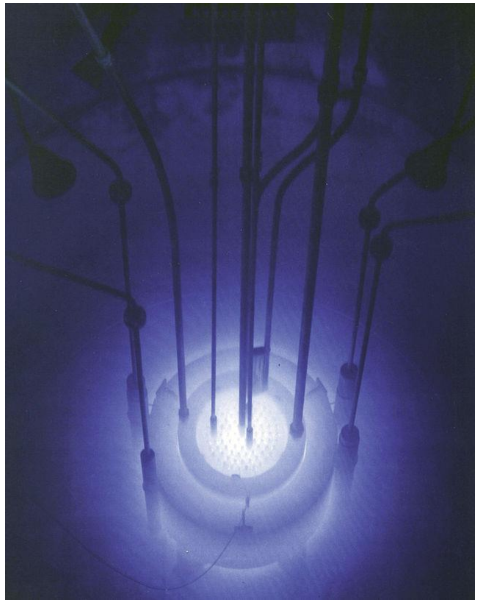
Cherenkov Effect

- The speed of light in a medium **s** ("phase velocity") is smaller than the speed of light in vacuum ***c*** by a factor of $\mathbf{n} = \frac{\mathbf{c}}{\mathbf{s}}$ ("refractive index").
- The relativistic speed β of a particle with speed **v** is just the percentage of the speed of light in vacuum: $\beta = \frac{\mathbf{v}}{\mathbf{c}}$
- When a charged particle travels at high speeds through a medium with a refractive index **n** and the particle speed **v** is higher than the phase velocity **s** in the medium, then coherent light is emitted. This is called Cherenkov light.
- The Cherenkov light is emitted under a fixed angle θ with respect to the particle trajectory that depends on the speed of the particle and the refractive index of the medium: $\cos\theta = \frac{1}{\mathbf{n}\,\beta}$





Cherenkov Detectors – Idea

- The Cherenkov effect offers a way measuring particle velocities in a non-disruptive way, the particle travels without loosing much of its originally momentum **p**.
- In a beamline, the particle beam momentum is selected with the help of dipole magnets and collimators, so it is known relatively precisely (in the order of percent or even less in our secondary beams).
- If you measure the velocity of a particle β and know its momentum **p**, then you can identify the particle, i.e. determine its mass **m**:

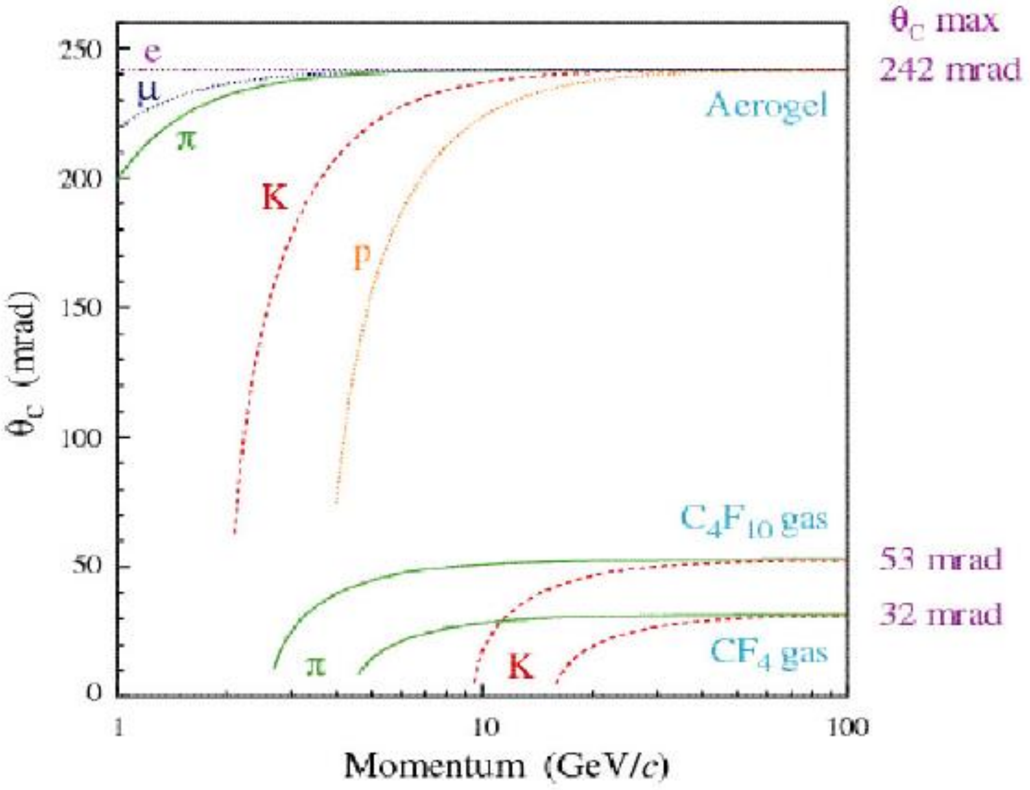
$$\mathbf{m} = \frac{\mathbf{p}}{\gamma\,\beta c}$$

With $\gamma = \frac{1}{\sqrt{1-\beta^2}}$

- The only thing you have to do is to provide a medium and to measure the emitted light.

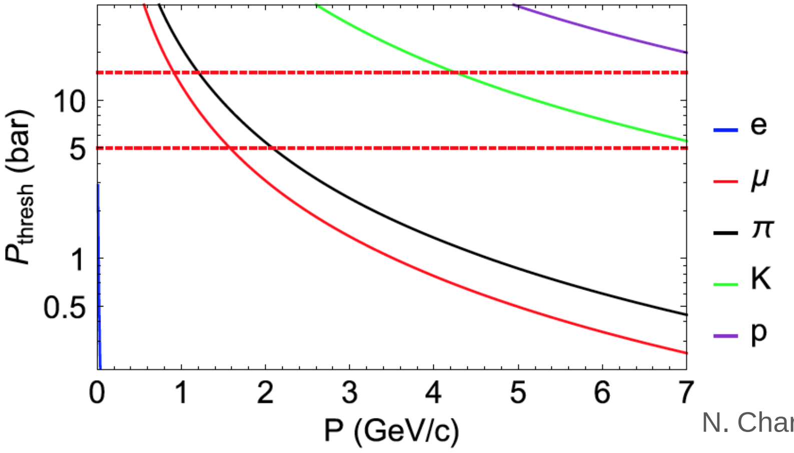
Threshold Detectors

- Normally, light (photon) detectors are relatively expensive. One idea is simply collecting all produced light and focusing it on a photon detector.
- But how would you then distinguish between particles?
  → Use the threshold behaviour of the Cherenkov effect.
- Light is only emitted if the particle speed is high enough, so the angle θ is larger then 0. This gives a natural threshold that depends on the refractive index (so the used medium) and the particle mass.

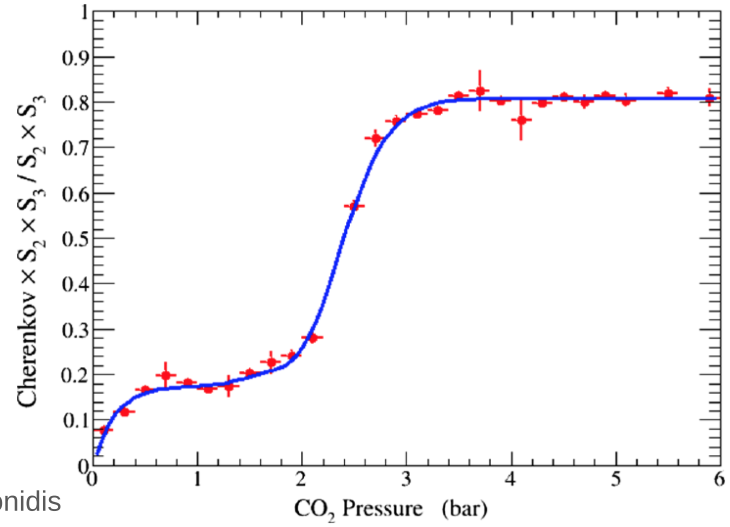


Threshold Detectors

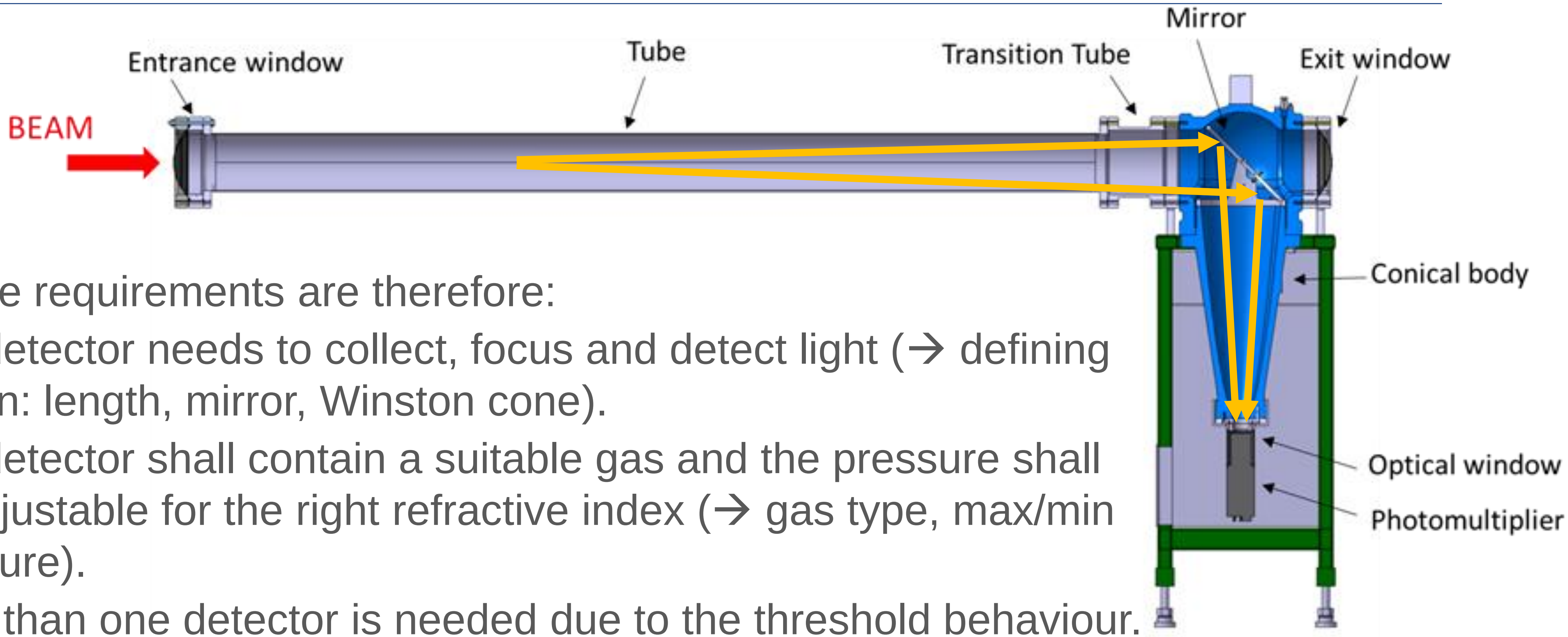
- Does that mean that you have to exchange the medium all the time?
  → No. Fortunately, the refractive index of a medium depends on its density in the case of a gas. As the density depends on the pressure, you can change the refractive index by changing the pressure.
- The downside is that you cannot clearly identify one particle, as you integrate the light of all particles over threshold. This means, one Cherenkov detector is usually not enough, besides for electrons.



N. Charitonidis



Requirements



- Principle requirements are therefore:
  - The detector needs to collect, focus and detect light (→ defining design: length, mirror, Winston cone).
  - The detector shall contain a suitable gas and the pressure shall be adjustable for the right refractive index (→ gas type, max/min pressure).
  - More than one detector is needed due to the threshold behaviour.
  - The detector material shall not interact too much with the particle to allow a non-destructive measurement (→ windows thickness).

Requirements for the East Area

- Two threshold Cherenkov detectors per beamline (T09/T10), ideally removable.
- Gas types: N / CO2 / C3H8 (R218) / C2H2F4 (R134a), easily exchangeable.
- Maximum gas pressures: 3.5 bar(g) / 5 bar(g) / 15 bar(g).
- Precision: ± 20 mbar (scans, precision of threshold, stability).
- The two refrigerants C3H8 (R218) / C2H2F4 (R134a) only up to a maximum pressure of 5 bar(g) to keep them from liquefying.
- Usability: Filling speed <1 hour for 15 bar(g) (frequent changes for the users, threshold scans).
- Gas quality/purity: Experimental quality (too much pollution means unknown refractive index).
- Vacuum for purging/cleaning and when the detectors are not needed (reducing the interaction probability of particles).

Thank you for your attention!

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