name: **group:**

Exercise Sheet 2 – Particle Physics – WS 2012/13

hand in: Tue 30th October (after the lecture or at INF 226, 3.104 by 4 pm)

2.1 Interaction of Particles with Matter (4 points)

a) **Estimate** the kinetic energy of the following particles after their material interactions:

- a muon with $E_{\text{kin}} = 400$ MeV traverses a 10 cm iron target
- a proton with $E_{\text{kin}} = 200$ MeV traverses a 20 cm iron target
- a charged pion with $E_{\text{kin}} = 1$ GeV traverses a 20 cm iron target

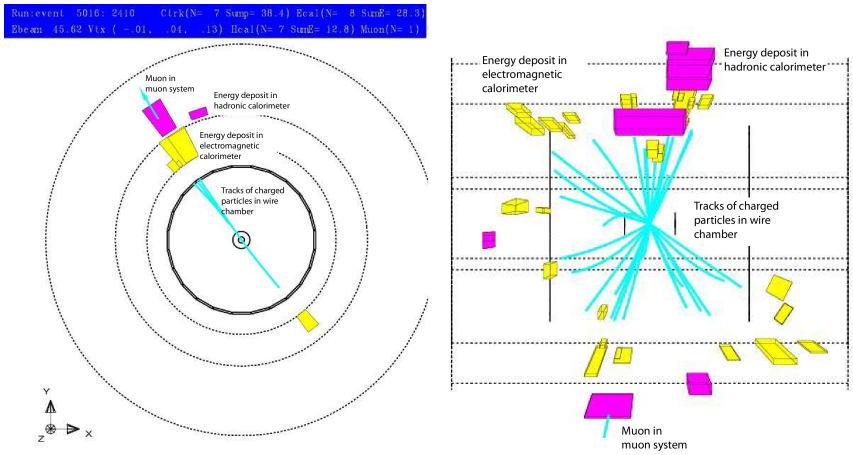
b) A particle with an energy of 5 GeV traverses water and emits Cherenkov radition. The light is detected at an angle of 40° to the flight direction. What is the mass of the particle? Which particle is this (take an ± 50 MeV uncertainty on the mass into account)?

2.2 Event Displays (8 points)

Look at the following event displays from the OPAL detector at the electron-positron collider LEP. Write down the final state particles and draw the according Feynman diagram.

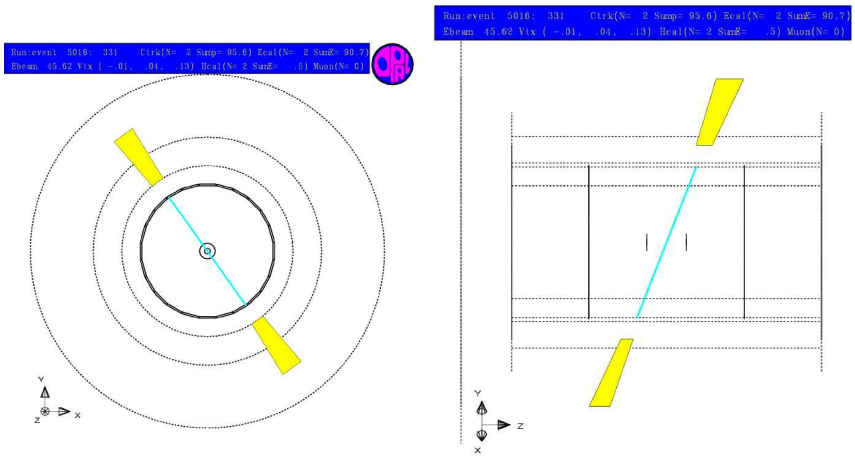
Hints: LEP was running at the Z resonance when these events were recorded, thus all reactions are of the type: $e^+e^- \to Z \to \ldots$. As the lecture will discuss later in more detail, single quarks can never be detected, however they form jets of many particles (mostly pions) that can be detected.

The symbols in the event displays are explained in the following figure (the view along the beam's direction and sideview show different events in this case only!).

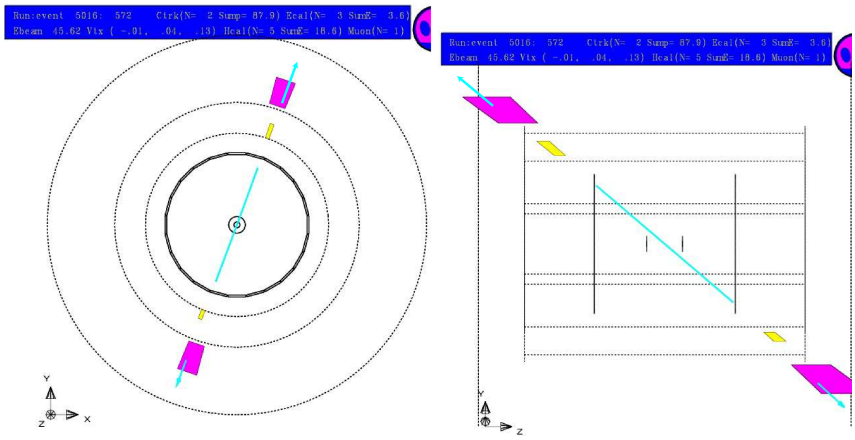


View along the beam's direction Sideview

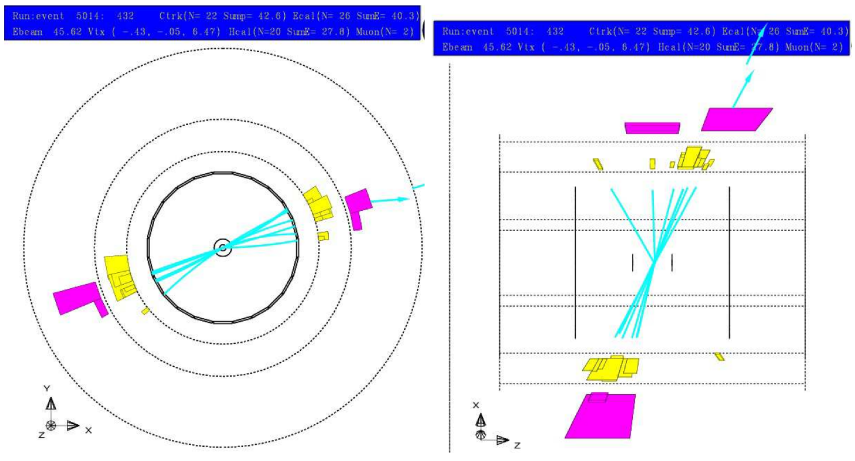
a)



b)



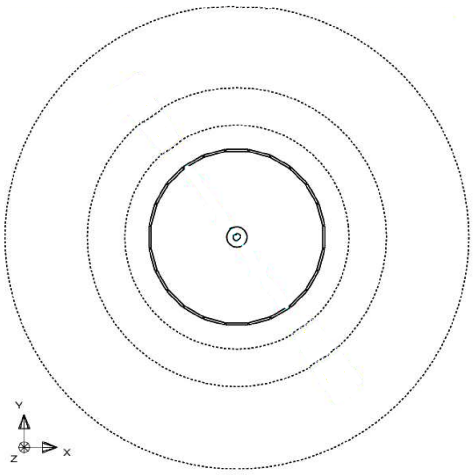
c)



d) Sketch how the following particles being produced at the center of the detector would look like in an event display:

- a photon
- a proton
- a neutron

Follow the scheme (colors, etc.) from above and label the particles.

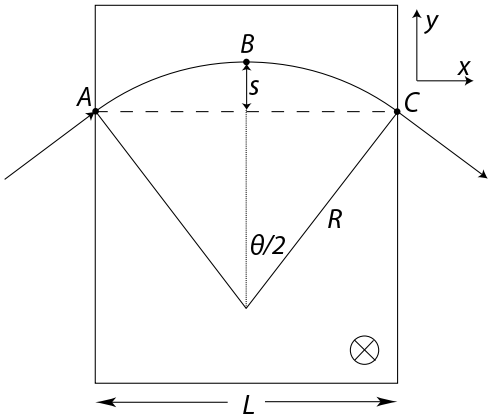


2.3 Tracking Detector Resolution (4 points)

In the homogeneous magnetic field B of a tracking detector, the track of a charged particle ($q = +e$) of momentum p (perpendicular to the B-field) can be measured.

a) What is the the relation between the radius R of the particle trajectory, the momentum of the particle and the magnetic field?

b) The track can be described by a lever arm L with a sagitta s (see figure below). In practice you can assume $L \gg s$.



Express the momentum p as a function of the lever arm L, the sagitta s and the magnetic field B. Calculate its value for $L = 1.7$ m, $s = 1$ cm, $B = 0.5$ T.

c) If the sagitta is as large as its measurement uncertainty σ_s, a curved track cannot be distinguished from a straight line in the detector. Thus the maximal measurable momentum is given by the precision of the measurement of the sagitta. By how much does the maximum measurable momentum improve if the detector length L is doubled (assume the number of measurements along the trajectory doubles accordingly).

2.4 Calorimetry vs. Tracking (4 points)

The ATLAS experiment at the LHC has a momentum resolution of about $\sigma_{p_T}/p_T = 5 \cdot 10^{-4} \cdot p_T[\text{GeV}] + 0.001$ for particles measured in the tracking system. In the electromagnetic and hadronic calorimeters the resolutions are $\sigma_E/E = \frac{10\%}{\sqrt{E[\text{GeV}]}} + 0.2\%$ and $\sigma_E/E = \frac{55\%}{\sqrt{E[\text{GeV}]}} + 2.3\%$, respectively.

Assume highly relativistiv electrons and charged pions traveling at a right angle to the beam axis ($p = p_T \approx E$). At which energies are the calorimetric measurements equally precise as the measurements in the tracker?