# Detector chapter questions

**Price of LHCb vs large experiments?**

75M CHF vs 300M CHF for ATLA and 550M for CMS

**Points on the LHCb upgrades**

**What is the hit coordinate resolution of the VELO? (pitch vs precision?)**

About 10ish um, due to charge sharing.

**What are the x, y coordinate resolutions in the OT?**

The x resolution is given by the drift time, 200 um. Drift time is calculated relative to LHC clock taking time-of-flight into account. Not sure about the y coordinate resolution, not quoted. Driven by the x-u-v-x geometry. In any case, the resolution in the bending plan is most important.

**How should energy resolutions for calorimeters be interpreted?**

What I am quoting is the statistical uncertainty plus an energy-dependent relative uncertainty due to systematic effects, such as calibration errors and non-uniformities. A constant term could have been included due to specific instrumental effects: presumably it’s negligible.

**Why exactly do muons penetrate?**

While the critical energy (where radiative processes start dominating the electromagnetic interaction, rather than ionisation) for electrons is 10 MeV, it is several hundred GeV for muons. Finally, in an ionisation interaction, the heavy mass of the muon relative to the electron means that is looses a relatively small fraction of its energy in any given interaction.

**The quoted radiation lengths for CALs are for what particles?**

Radiation length is the typical electromagnetic interaction length for electrons where E >= 10 MeV, so that bremsstrahlung and pair-production dominates the interaction. For lower energies ionisation is dominating.

The nuclear interaction length is then the mean distance of a strongly-interacting particle.

**Fig 3.15: why is 12 lower than 11 in the right plot, if multiplicity is the underlying cause?**

**Why lead in the ECAL?**

We want to maximize the hadronic interaction length compared to the radiation length, so that hadrons loose relatively little energy in the ECAL. This ratio satisfies , so we want as heavy an absorber as possible

**Elements of the Bethe formula**

Beskriver ioniserende interaction med materiale.

1/beta^2 er intuitiv: delta P propto tid i Delta x propto 1/v, så Delta E propto 1/v^2

Når dE/dx stiger igen, er det pga. Mulighed for større energioverførsler i interaktioner med elektroner for meget højenegi partikler … sådan ca.

## Detector types I need to understand

**Silicon strips (VELO, TT, IT)**

n-side is negatively doped: too many electrons

p-side is positively doped: too many holes

In central region, electrons flow to fill holes, leaving no free charge carriers. Net effect is a positively charged area towards the n-side and a negatively charged area on the p-side.

Hence, electrons will tend not to flow in the p->n direction.

We can reverse bias, putting a positive potential on the n-side. The space charge described above means that for reasonable voltages, no current can flow.

If, however, a particle excites an electron into the conduction band, the electron

**Drift tubes (OT) – I use drift tubes and drift chamber, is one of these wrong?**

Just use tubes. Should adjust text. I kinda understand the point, don’t I?

**Basic E/H calorimeters with scintillators for light detection**

I understand the principle …

**Shashlik structure – what is that?**

Just means interspaced absorbers and scintillators, with a wave-length-shifting fibre that takes the light out to the photo detectors.

**Are the photo detectors really within the acceptance?**

Yes ….

**Multi-wire proportional chambers (muon stations)**

Honestly simple enough, at the level of detail that I’ll need (hopefully!)

**Triple gas electron multiplier detector (central M1)**

In the because wire chambers do not age well at high intensities. Why?

In the high E field cascades, a bunch of chemical reactions take place, leaving deposits of all sorts on the wires.

In a multiple GEM detectors, the gain is achieved in multiple regions, allowing each of them to operate at at voltage where fewer chemical reactions are induced.

**Kalman filter again**

Consider measurements at each detector layer as “updates”.

1. Predict x\_k
2. Filter: improve x\_k based on measurement m\_k
3. After all stages have been made, smoothen: update all x\_k-n based on all measurements

Can be made w/o inverting large matrices. Non-linear transport equations and measurement equations linearised. Introduces error: fit can be repeated iteratively to minimise impact.

Track parameters at each z are (x, y, t\_x, t\_y, p/q)

Multiple scattering and energy loss in material taken into account in the transport steps

## Tracking algoritms

Am I saying something slightly wrong about the long tracks?