Vertex Detector narrative
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Flavour tagging and reconstruction of vertices originated by short-lived particles are essential for the exploitation of the physics reach at particle colliders. In essence, the key performance indicator for a Vertex Detector (VD) is the resolution on the particle trajectory impact parameter ($\sigma_{i.p.}$). In the plane orthogonal to the beam axis, this can be written as:

$$\sigma_{i.p.} = a \oplus \frac{b}{p \cdot sin^{3/2}\theta}, \tag{1}$$

where p is the particle momentum and θ is the polar angle with respect to the beam axis. The parameter a is the asymptotic term and depends on the detector geometry and the single layer resolution on the reconstruction of the particle impact point. For the sake of clarity, in a two-layer system this can be written in a simplified form as:

$$a = [(n+1)^2 + n^2]^{1/2} \times \sigma_{point}, \tag{2}$$

where $n = \frac{R_{in}}{\Delta R}$ is the ratio between the radius of the innermost VD layer and the lever arm between the outer and inner layer and σ_{point} is the impact point resolution, presumed to be equal for the two layers.

The parameter b is related to the multiple scattering. Again, in a simplified form, this can be related to the effect due to the Coulomb diffusion in the layer closer to the interaction point and written as:

$$b = 13.6 \times 10^{-3} \times \sqrt{\frac{x}{X_0}} \times R_{cl} \quad [m], \tag{3}$$

where x is the layer thickness, X_0 is the radiation length and R_{cl} is the radial position of the scattering layer.

The required figures at the next generation electron-positron colliders are $a \leq 10\mu m$ and $b \leq 20\ \mu m\, GeV/c$, representing a significant step forward with respect to the previous and current experiments, as reported in Table 1

Accelerator	a [μm]	b [$\mu m\, GeV/c$]
LEP	25	70
SLC	8	33
LHC	12	70
RHIC-II	13	19
Next Generation e^+e^- colliders	10	20

Table 1: Value of the impact parameter resolution terms for a class of experiments at colliders.

In the current design, the vertex detector will be housed in a volume constrained by the beam pipe and by the drift chamber. Presuming the former to be located at a radius of 16 mm and the latter with an inner radius around 210 mm, an estimate of the required single point resolution can be obtained by Eq.2 when $R_{in} = 17mm$ and $\Delta R = 183mm$, leading to an asymptotic term $a = 1.1 \times \sigma_{point}$. This is constraining the spatial resolution not to exceed $5\mu m$, well compliant with results already achieved today. In order to evaluate the required material budget, the effect of the multiple scattering in the beam pipe shall be considered; with a 1mm thick Berillium pipe at 16mm radius, the b terms turns out to be $12\,\mu m\,GeV/c$, setting an absolute limit to the contribution by the inner layer of the VD to $16\mu m\,GeV/c$, or a thickness below $0.5\% X_0$.

In order to guarantee redundancy and maximise the efficiency of the pattern recognition, a geometry based on more layers shall be envisaged. The two more natural choices are either a set of equidistant layers or two groups at the inner and outer radii. As exemplary illustration, the impact parameter resolutions are shown in Fig. XXX for two geometries [**I think it would be important here to show the results of the simulation. If I'm not mistaken, the geometry with R = 17, 23, 31, 180 and 200 mm has already been performed. I think it would be nice to see how it goes with equidistant layers as well.**]
. A barrel geometry in the central region shall be complemented by either disks or end-caps, in order to guarantee an angular coverage down to a polar angle of 10 degrees [**is there an exemplary design to be shown? and a figure on tracking in the low angle region?**].

As of today, a number of pixel detector technologies and architectures have been shown to be able to feature the required characteristics, the baseline single point resolution and particle detection efficiency. The most recente advances are the Inner Tracker System (ITS) of the ALICE detector, currently under construction, and the BELLE-II Vertex Detector, being commissioned. The ITS is a 7 layer detector for a total area of $10m^2$, based on Monolithic Active Pixel Sensors (MAPS) produced with an industrial process; the BELLE-II VD is based on DEPFET detectors, manufactured at the MPG-HLL laboratory. Both systems are exemplary illustration of the potential of the most recent developments in low-mass, low-power, high resolution position sensitive detectors and set the ground for a dedicated development, together with several complementary concepts, designs and technologies [**here I would add a rather long list of references!**]. In fact, whether radiation hardness is not expected to be an issue and the required resolutions are guaranteed by existing detectors, the proposed sensors for an experiment at the FCC shall comply with the beam background occupancy [**any estimate we can quote?**] and the event rate at the Z pole. The requests have an impact on the granularity and the read-out speed, impacting on the architecture (e.g. binary vs. analog pixels; optimization of the zero-suppression scheme) and eventually on the power consumption and the cooling system, affecting the system design and the material budget.