Homework n.5

a.a. 2023-2024

Monte Carlo method and simulation

1) Evaluate the integral $I = \int_{-\infty}^{+\infty} \frac{1}{1+x^2}\, dx$ using two Monte Carlo methods:
   A) miss or hit
   B) the mean method.
   C) From the obtained value, considering that $I = \pi$, get an estimate of the irrational number π.

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2) Generate a histogram with 10000 events extracted from the $f_1(E)$ part of the energy spectrum $f(E)$ of Homework n.1 (consider only $f(E) = f_1(E)$)
including the effect of a gaussian resolution $\sigma(E)/E = 10\%/\sqrt{E(\text{MeV})}$.
Consider that to implement the resolution, each energy value E_i extracted from the spectrum $f(E)$ has to be smeared for the resolution $\sigma(E_i)$.

Hint: fill the histogram with the smeared energy according to resolution:
$E_i' = g[E_i; \sigma(E_i)] = E_i + \sigma(E_i)\, g[0;1]$
where $g[0;1]$ is a random variable distributed as a gaussian with zero mean and unitary standard deviation.

Compare qualitatively the histogram with the result obtained evaluating the convolution integral.

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3) Reproduce the experimental distribution of the KL impact points on the calorimeter and decay distances from the IP in Homework n.4.

Simulate:

- angular distribution of KL (neglect the Phi boost): $dN/d\Omega \propto \sin^2(\theta)$
- decays of KL according to an exponential law and distribution of the impact points and times of arrival of KL on the surface of the calorimeter;
  approximate the internal surface of the calorimeter as a cylinder of radius 200 cm and height 340 cm, centered at IP, and with the axis along the beam; for times, consider as T_0 the production of KL at IP. Include resolution effects according to detector performance (assume gaussian resolutions – see last slide).
- distribution of KL decay vertices in the DC volume (assume a resolution of 1.5 cm on the x,y, z coordinates of the reconstructed vertex).
  Neglect interaction of KL with beam pipe and DC inner wall.

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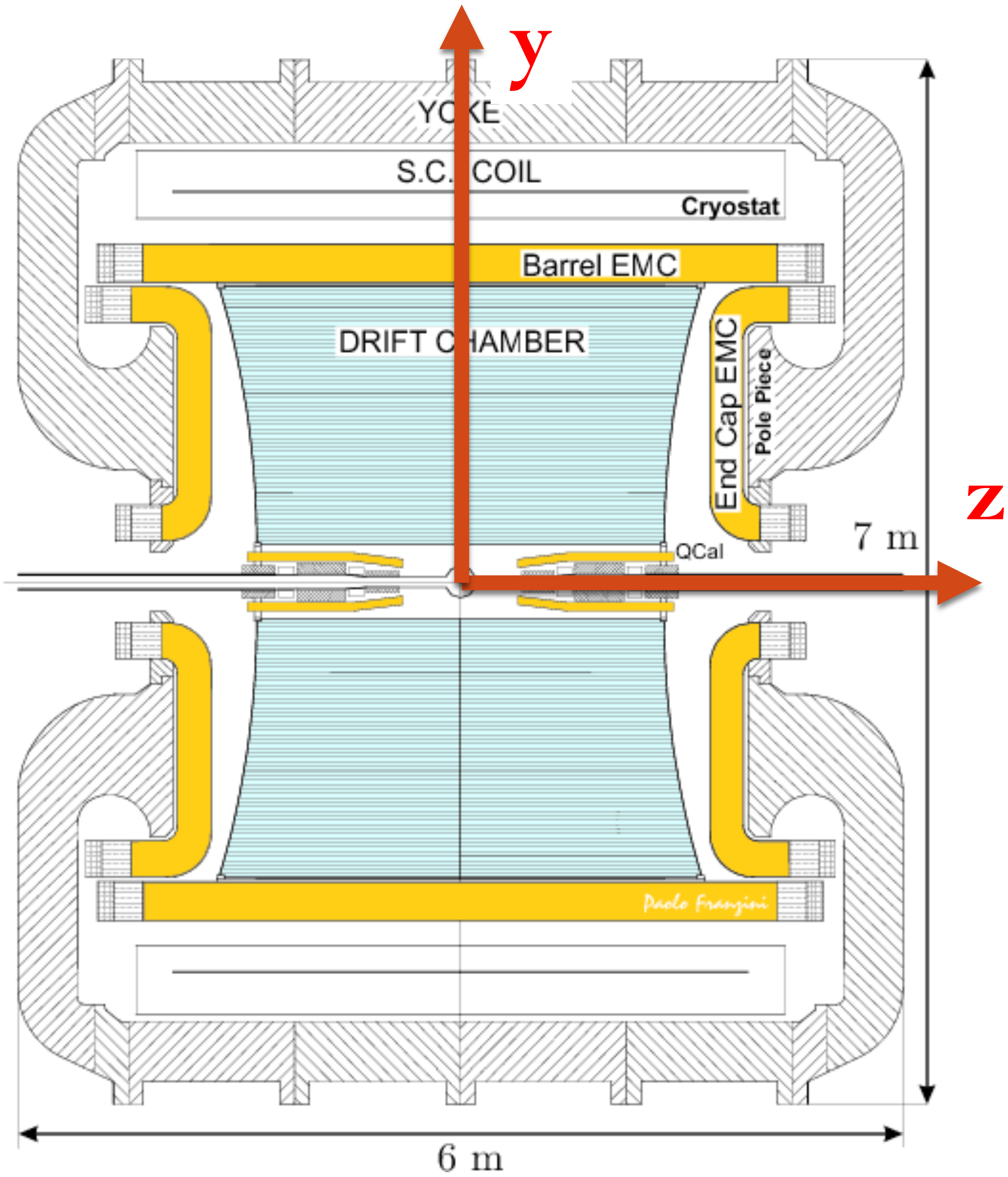
Evaluate:

- the geometrical acceptance for KS-tag using "KL-crash" on the calorimeter. Take into account also the cuts implemented in the analysis (e.g. $\theta > 21°$) in Homework n.4.
- the distribution of time of arrival of KL on the calorimenter.
- the distribution of the decay length (from IP) for KL decaying inside the DC volume (approximate the DC volume as the cylinder considered for the internal surface of the calorimeter).
- the distribution of the transverse distance from IP (transverse with respect to the beam direction along the z axis) for KL decaying inside the DC volume.
- the geometrical acceptance for KL decays inside the DC volume.



Calorimeter

Lead-Scintillating fibers calorimeter

Read-out through 4880 PMTs

Energy and time resolutions

$$\frac{\sigma(E)}{E} \cong \frac{5.7\%}{\sqrt{E(GeV)}} \quad ;$$

$$\sigma(t) \cong \frac{54\ ps}{\sqrt{E(GeV)}} \oplus 100\ ps$$

For barrel cluster position resolution in the direction along the fibers:

$$\sigma(z) \cong \frac{1.2\ cm}{\sqrt{E(GeV)}}$$

in the direction transverse to fibers:

$$\sigma(x,y) \cong 1.3\ cm$$

For End-caps:

direction along the fibers:

$$\sigma(y) \cong \frac{1.2\ cm}{\sqrt{E(GeV)}}$$

direction transverse to fibers:

$$\sigma(x,z) \cong 1.3\ cm$$