2009–03–18

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Yesterday we did... nothing, really. We discussed some concepts pertaining to accelerators: The cyclotron frequency: $\omega = e\,B/\gamma m$ where $\gamma = E/mc^2 = 1/\sqrt{1-v^2}$.

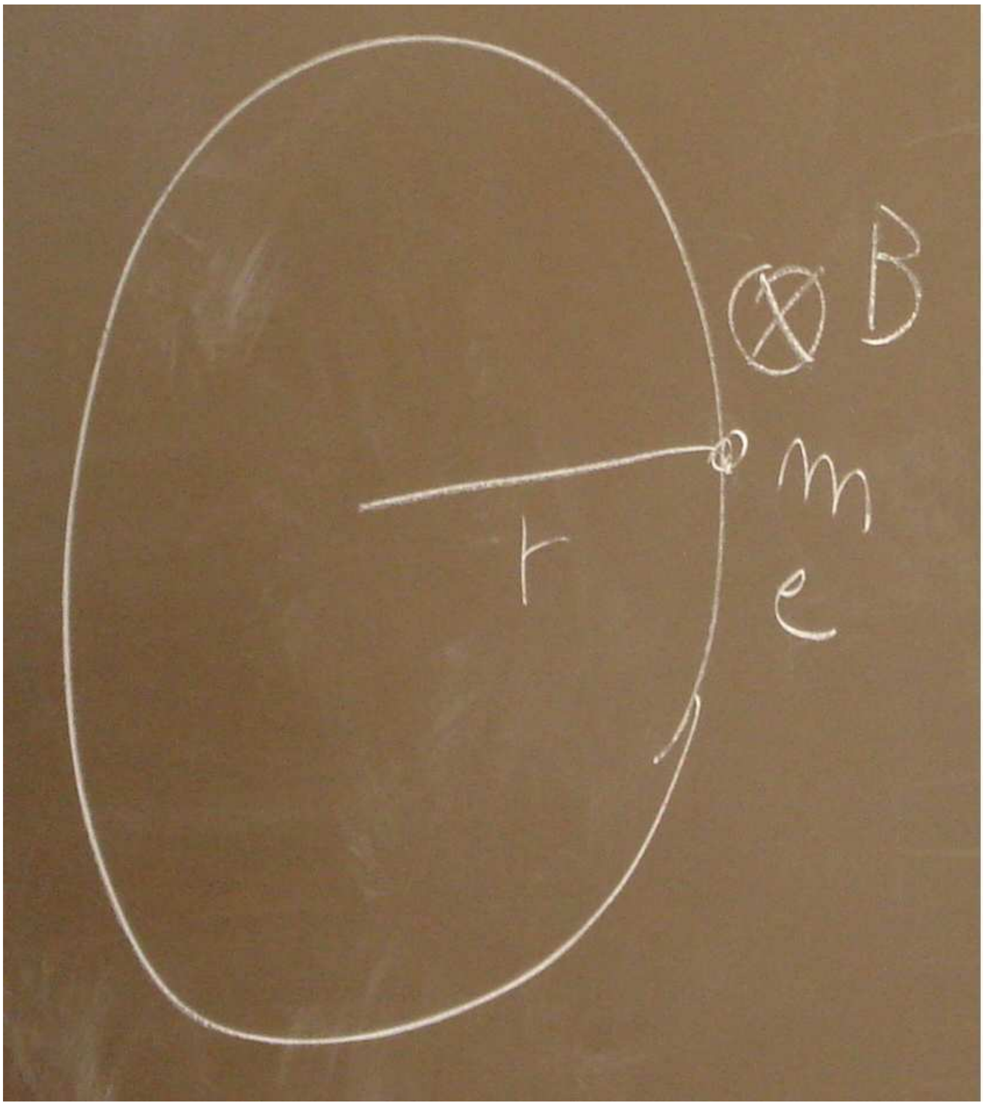

Figure 1.

Ultra-relativistically: $v \simeq c$

$$\frac{1}{r} \simeq \frac{e\,B}{E} \quad \Rightarrow \quad E = e\,B\,r$$

Power radiated, Larmer:

$$P = \frac{2\,e^2}{3} \underbrace{g^4 \frac{v^4}{r^2}}_{a^2}; \quad P \propto \left(\frac{E}{m}\right)^4 \cdot \frac{1}{r^2}$$

Important parameters:

- Centre of mass energy: $E_{\mathrm{LHC}} \simeq 14\,\mathrm{TeV}$.
- Luminosity (with units of a flux): $\mathcal{L}_{\mathrm{LHC}} \simeq 10^{34}\ \mathrm{cm}^{-2}\ \mathrm{s}^{-1}$.

The number of interesting events per unit time is $N = \sigma\,\mathcal{L}$ where σ is called the *total cross section*.

This is what we did yesterday.

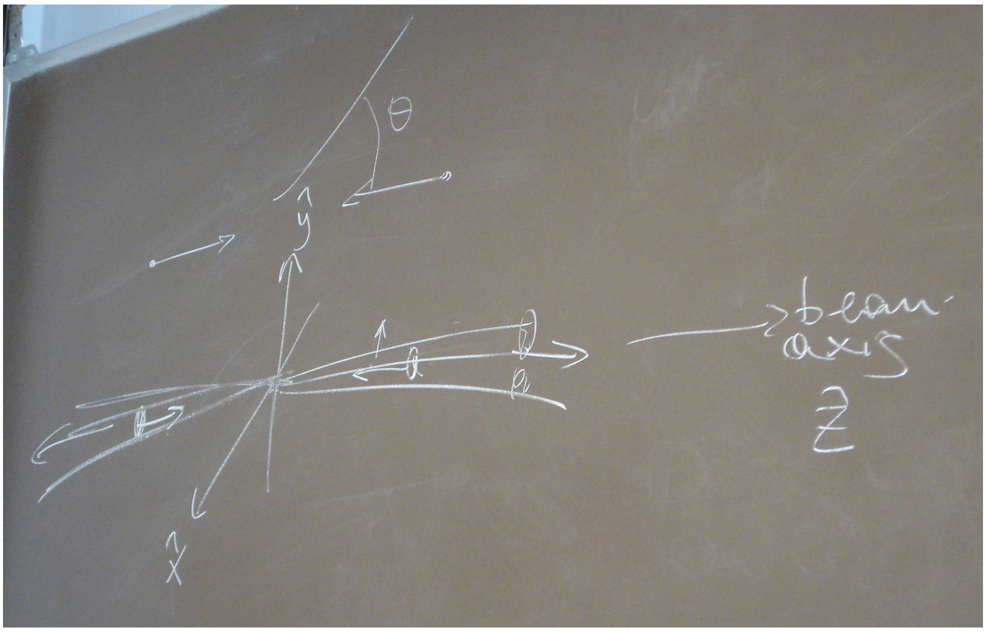

Figure 2.

For proton-proton interaction $\sigma \sim \pi r^2 = 30\,\mathrm{mb}$.

$$1\mathrm{b} = 1\,\mathrm{barn} = 10^{-24}\,\mathrm{cm}^2$$

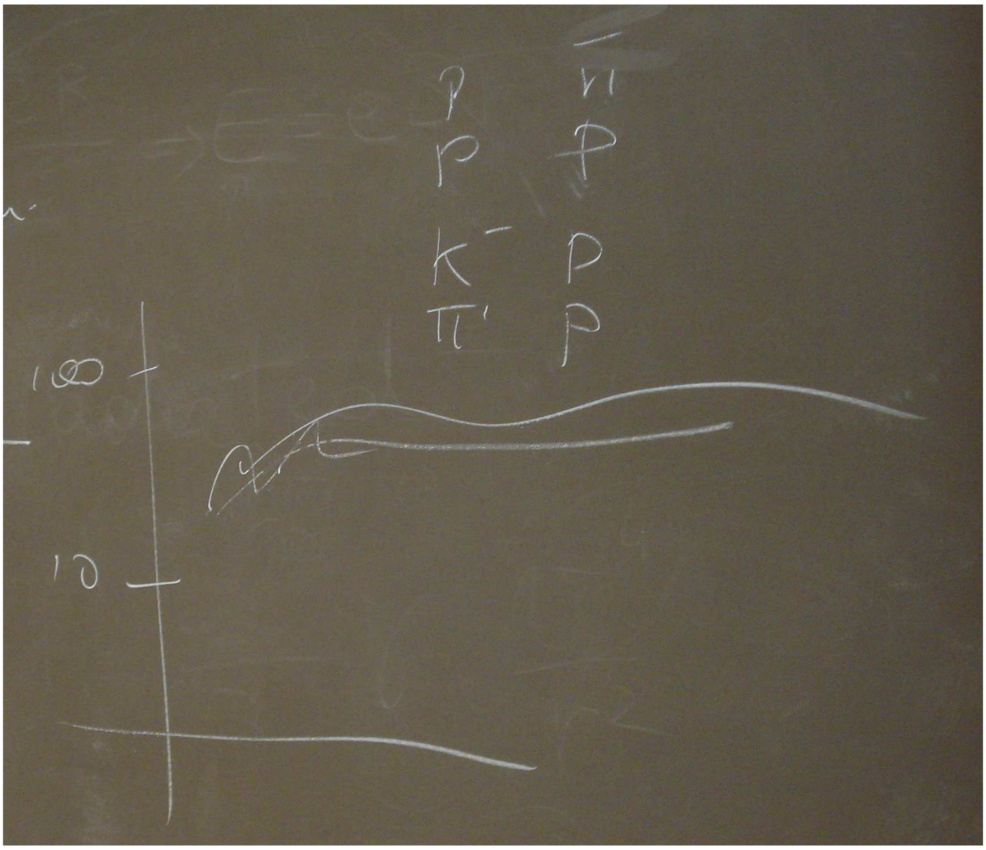

Figure 3. Hadron scattering σ between 10 b and 100 b.

Electrons, as far as we know, do not have an inner structure. $e^- + e^-$ with energy $E_{\text{tot}} = \sqrt{s}$ in the centre of mass frame.

$$\sigma \sim \left(\frac{e^2}{4\pi}\right)^2 \frac{1}{s}$$

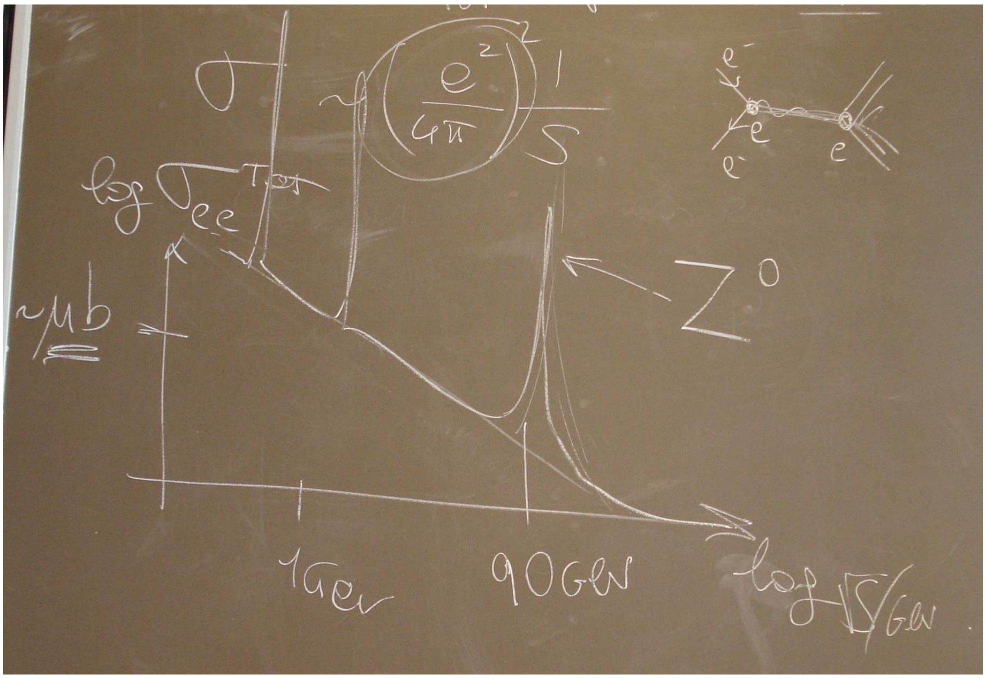

Figure 4.

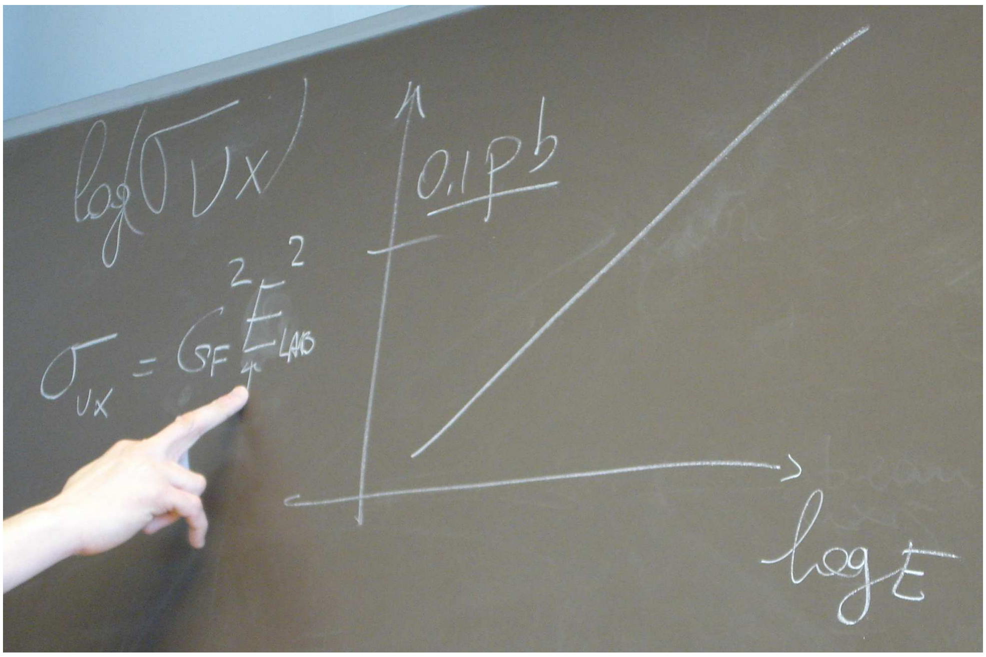

Figure 5. For neutrinos we have cross sections such as 0.1 pb.

$p+p\rightarrow ?$

Hard processes. Processes where one pointlike particle inside the one proton hits a pointlike particle inside the other, rather than doing "drop-like" scattering.

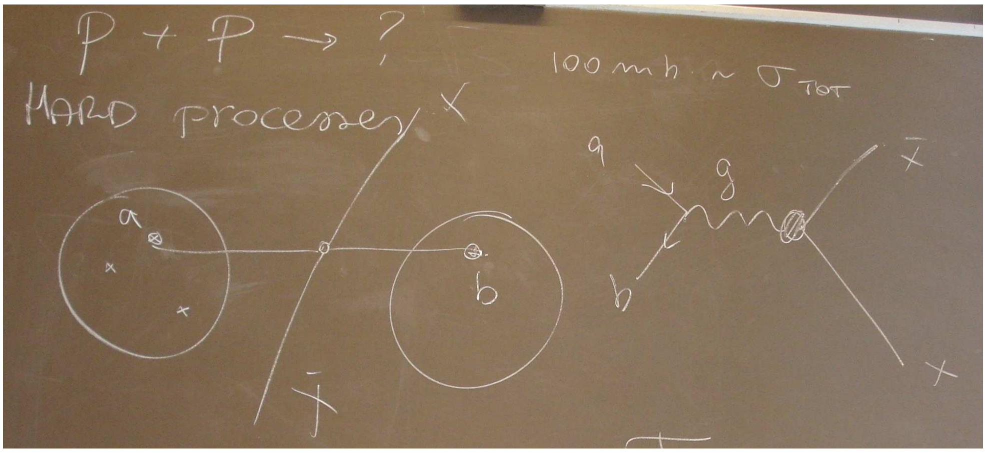

Figure 6.

$$\sigma_{\text{Hard}} = \frac{g_s^4 \cdot \mathfrak{Q}}{s} \sim 40\,\text{pb}$$

$p+p$, $\sigma_{\text{tot}} = 100\,\text{mb}$, $\sigma_{\text{Hard}} = 40\,\text{pb}$, $N = \mathcal{L}\,\sigma$ where $\mathcal{L} = 10^{34}\,\text{cm}^{-2}\,\text{s}^{-1}$.

Tot: $N \sim 10^9\,\text{events/s}$.

Hard: $N \sim 10\,\text{events/s}$.

["Why this need to finish the sentence? Let's take a break.")

Integrated luminosity. $\mathcal{L}(t)$

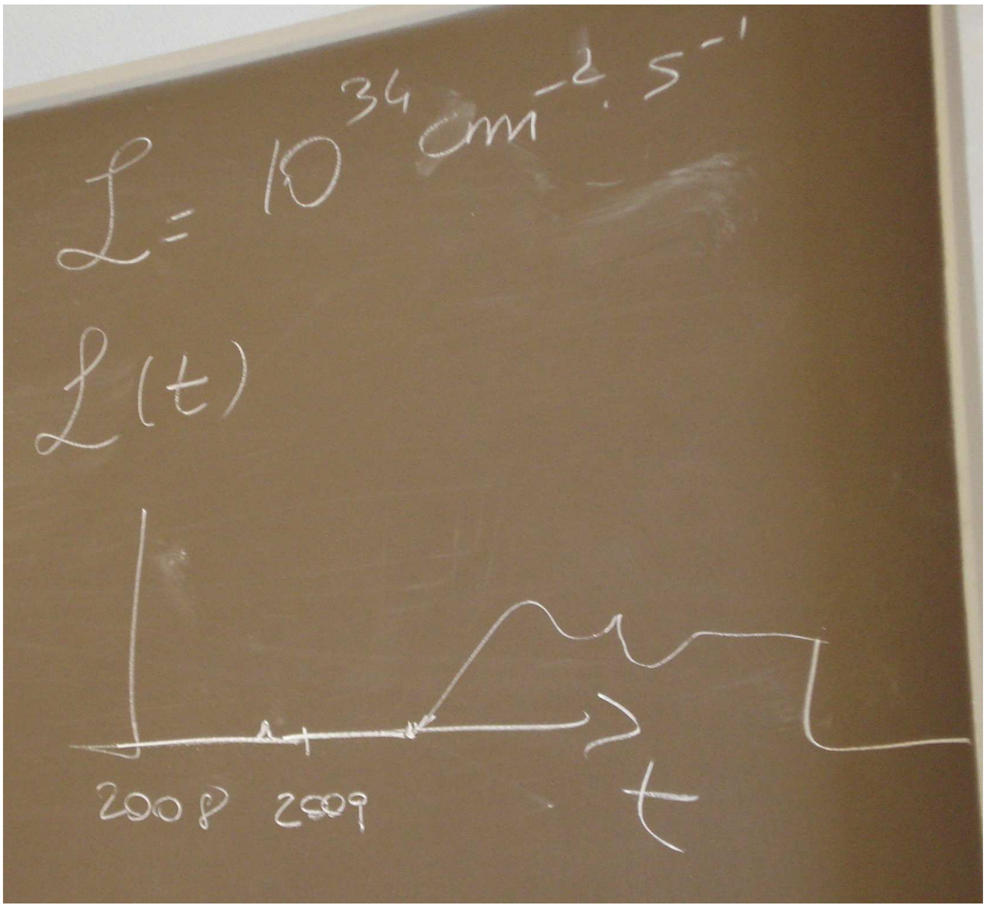

Figure 7. Luminosity over time.

$$\int_{t_{\text{start}}}^{t_{\text{now}}} \mathcal{L}\,\mathrm{d}t$$

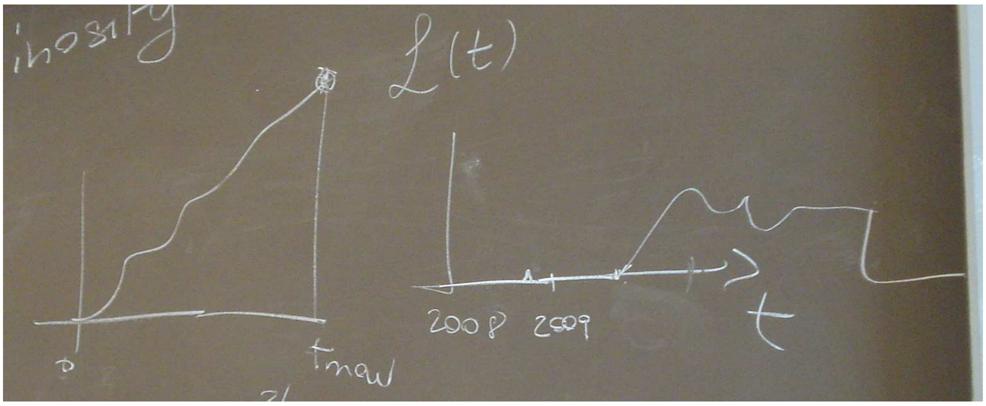

Figure 8. Left: integrated luminosity over time: a monotonously increasing function.

1 perfect year: $\pi \cdot 10^7 \cdot 10^{34} \sim 3 \times 10^{41}\,\mathrm{cm}^{-2} = 300\,\mathrm{fb}^{-1}$.

$$\sigma_{\mathrm{Hard}} \rightsquigarrow 40000\mathrm{fb} \times \mathcal{L} = 12 \cdot 10^6\,\text{events/year}$$

$$\sigma_{\mathrm{susy}} \sim 3000\,\mathrm{fb} \times 300\,\mathrm{fb}^{-1} \sim 900000\,\text{susy particles/year}$$

$$\sigma_{\mathrm{Higgs}} \sim 2000$$

$$\sigma_{Z'} \sim 2\,\mathrm{fb};\, 600\, Z'/\mathrm{year}$$

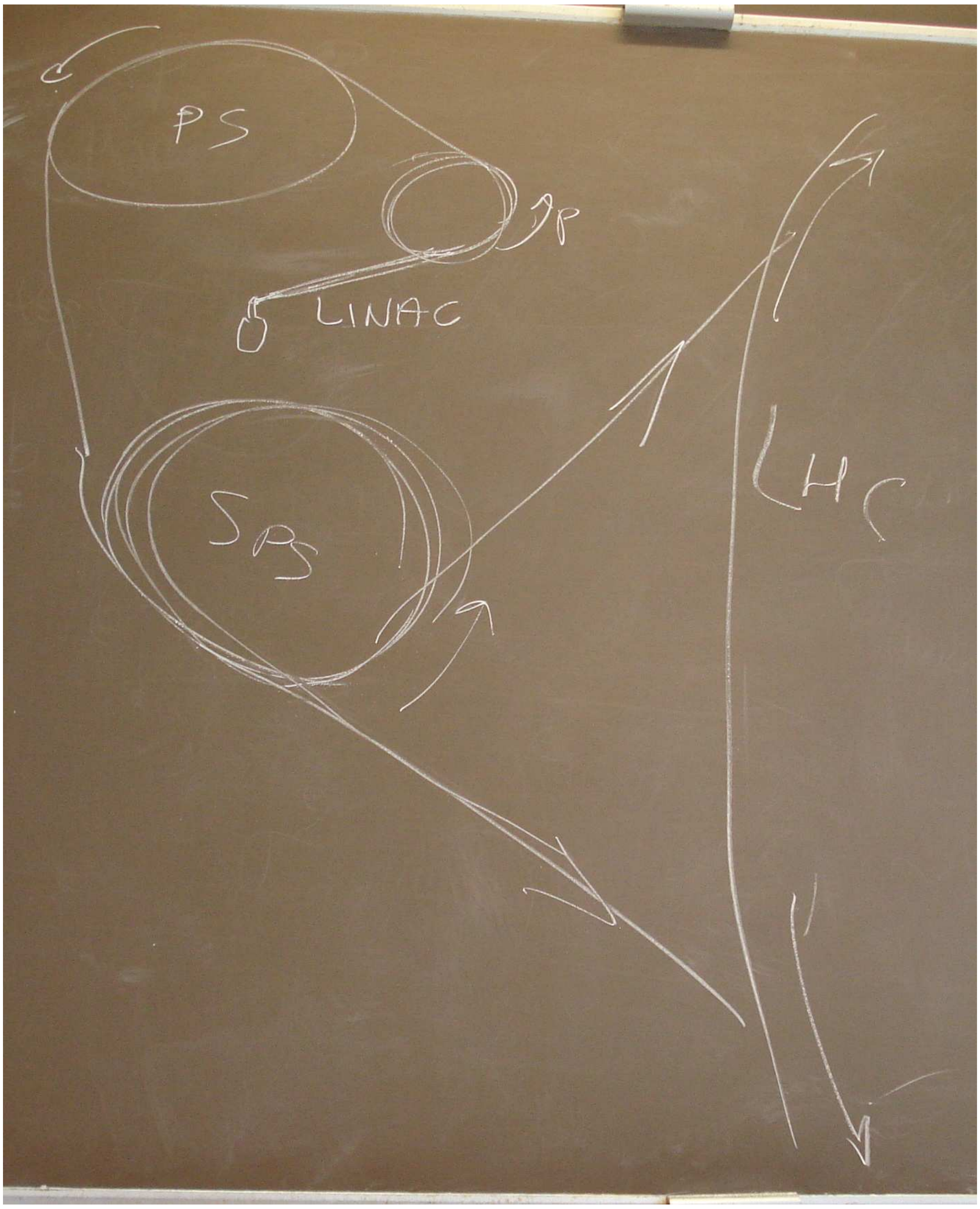

Figure 9. LHC: booster, proton synchrotron, super proton synchrotron,...

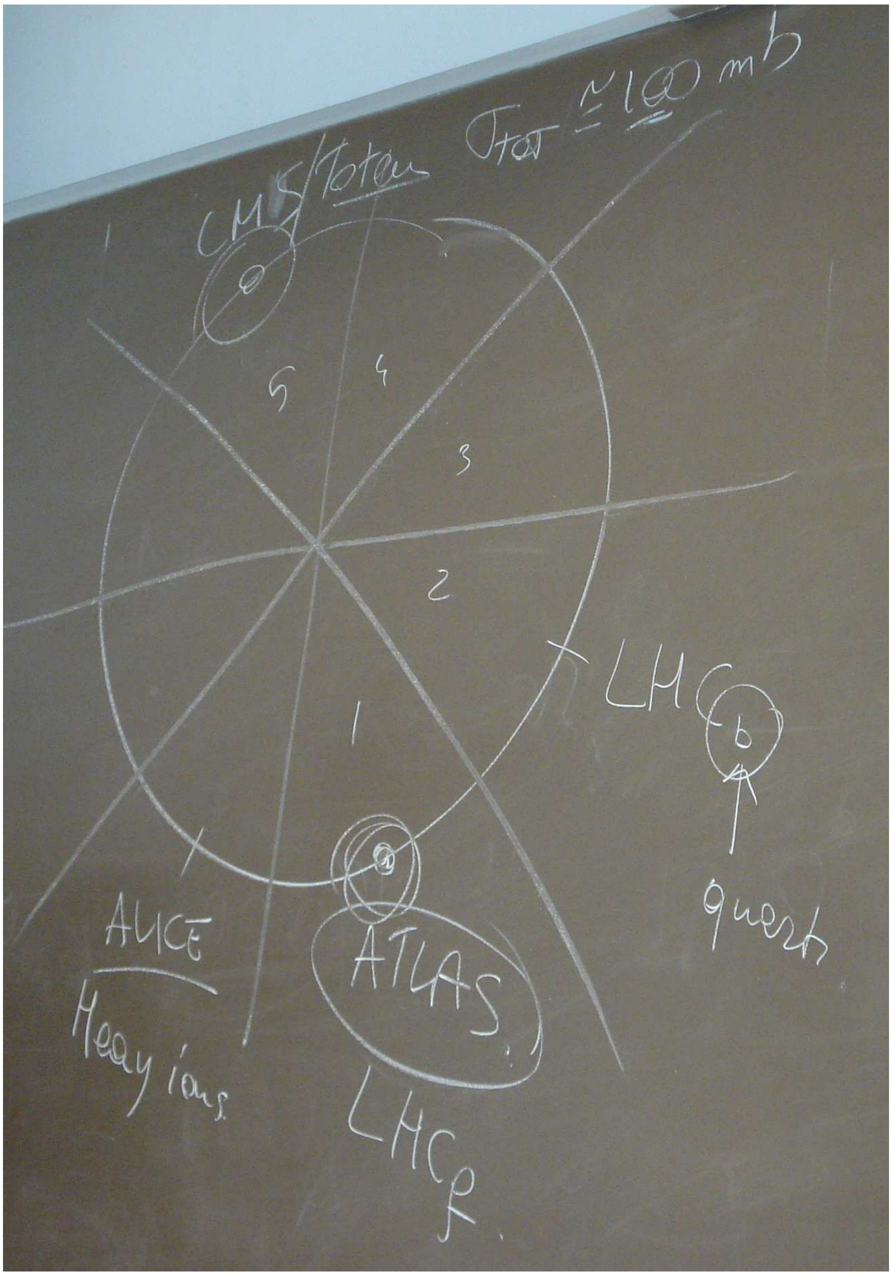

Figure 10. Octants and experiments

Figure 11. Detectors

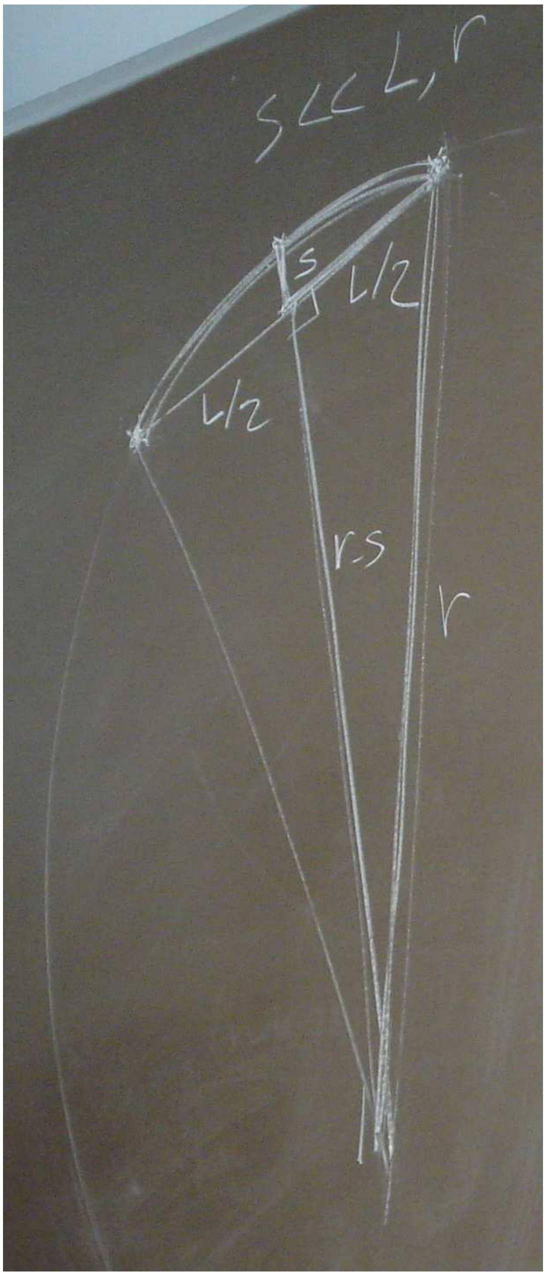

Figure 12.

$$r^2 = (r - s)^2 + \left(\frac{L}{2}\right)^2$$

$$r^2 = r^2 - 2\,r\,s + s^2 + \left(\frac{L}{2}\right)^2$$

$s \ll L, r$:

$$r \simeq \frac{L^2}{8s}.$$

$$\omega = \frac{v}{r} = \frac{e\,B}{\gamma m}$$

$$P = \frac{e\,B\,L^2}{8\,s} = e\,B\,r, \quad P = v\,\gamma\,m$$

$$\left|\frac{\Delta P}{P}\right| \sim \left|\frac{\Delta s}{s}\right| \sim \frac{8\,p}{3\,B\,L^2}\,|\Delta s|$$

Review of Quantum Field Theory

Decay:

$$A \to C_1 + C_2 + \cdots + C_n$$

We want to calculate the decay rate Γ.

Scattering:

$$A + B \to C_1 + \cdots + C_n$$

Scattering cross section σ.

Scattering amplitude, with time evolution operator U:

$$\langle C_1, \boldsymbol{p}_{C_1}, s_{C_1}; \ldots, s_{C_n} | U(t = +\infty, t = -\infty) | A, \boldsymbol{p}_A, s_A; B, \boldsymbol{p}_B, s_B \rangle =$$

$$= \mathrm{i}\,\mathcal{M}_{s_A, s_B, \ldots, s_n}(\boldsymbol{p}_A, \boldsymbol{p}_B, \boldsymbol{p}_{C_1}, \ldots, \boldsymbol{p}_{C_n})\,(2\pi)^4\,\delta^{(4)}(p_{\text{in}} - p_{\text{out}})$$

$\mathcal{M}$ will turn out to be free of δ-functions.

$$\mathrm{d}\sigma = \frac{1}{4\sqrt{(p_A \cdot p_B)^2 - m_A^2 m_B^2}} |\mathcal{M}|^2 \cdot \mathrm{dL}\textsc{ips}_m$$

where $\mathrm{dL}\textsc{ips}_m$ is the phase space factor.

B rest frame.

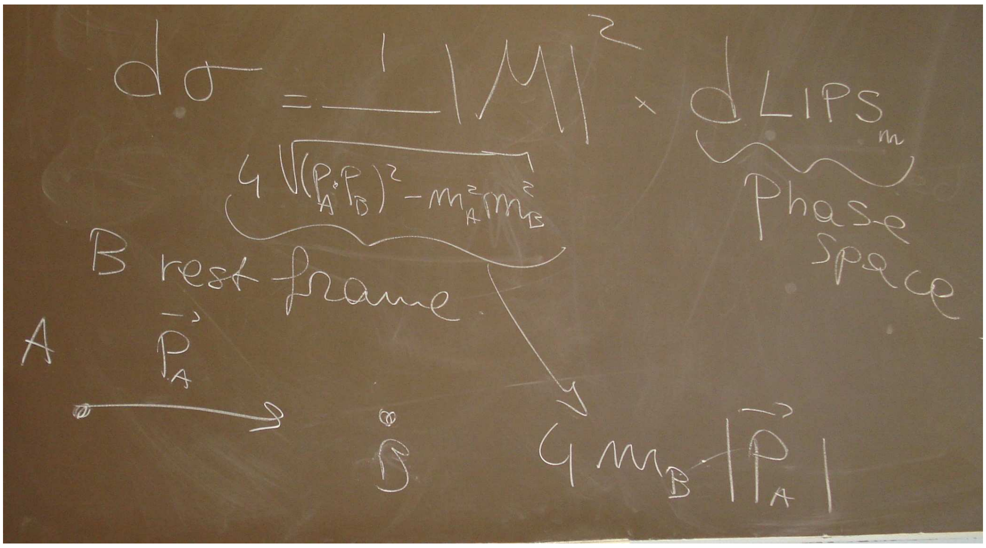

Figure 13.

$$4\sqrt{(p_A \cdot p_B)^2 - m_A^2 m_B^2} \to 4\,m_B\,|\boldsymbol{p}_A|$$