IONS AT A FUTURE HADRON COLLIDER: SOME BASIC NUMBERS

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A five-year international design study called Future Circular Colliders (FCC) is being initiated. The main emphasis is on a hadron collider (Future Hadron Collider) with a centre-of-mass energy of the order of 100 TeV in a new 80–100 km tunnel as a long-term goal. The design study includes a 90–400 GeV lepton collider, seen as a potential intermediate step. It also examines a lepton–hadron collider option.

This document collects a few basic numbers that can be useful in the discussion about physics with nuclear beams at a Future Hadron Collider (FHC).

1. Machine parameters

For a centre-of-mass energy $\sqrt{s_{pp}} = 100$ TeV for pp collisions, the relation $\sqrt{s_{\rm NN}} = \sqrt{s_{pp}}\sqrt{Z_1 Z_2/A_1 A_2}$ gives $\sqrt{s_{\rm NN}} = 39$ TeV for Pb–Pb collisions and 63 TeV for p–Pb collisions. The rapidities of the proton and Pb beams are 11.6 and 10.6, respectively.

The reference values for the peak instantaneous luminosity and for integrated luminosities per month of running are reported in Table 1, in comparison with the cases for LHC (for Run 2 and for Runs after the Long Shutdown 2).

Table 1. Peak luminosity and Integrated luminosity per month of running.

	LHC Run 2 [1]	LHC after LS2 [1]	FHC [2]
Pb–Pb peak $\mathcal{L}$ (cm^{-2}s^{-1})	10^{27}	5×10^{27}	7.3×10^{27}
Pb–Pb $L_{\rm int}$ / month (nb^{-1})	0.8	1	8
p–Pb peak $\mathcal{L}$ (cm^{-2}s^{-1})	10^{29}	t.b.d.	1.2×10^{30}
p–Pb $L_{\rm int}$ (nb^{-1})	80	t.b.d.	1000

2. Lead–lead collision properties

Table 2 reports some basic parameters for central Pb–Pb collisions (0–5%). The charged particle multiplicity, transverse energy and two-pion Bose-Einstein correlation parameters are extrapolated vs. $\sqrt{s_{\rm NN}}$ using parametrizations that describe the existing data. In particular:

- $\mathrm{d}N_{\rm ch}/\mathrm{d}\eta$ (at $\eta = 0$) $\propto (\sqrt{s_{\rm NN}})^{0.3}$ [3];
- Total $N_{\rm ch} \propto 0.512\,(\sqrt{s_{\rm NN}})^{0.3} \ln s_{\rm NN} + 1.962$ with $\sqrt{s_{\rm NN}}$ in GeV [4];
- $\mathrm{d}E_{\rm T}/\mathrm{d}\eta$ at $\eta = 0 \propto 0.46\,(\sqrt{s_{\rm NN}})^{0.4}$ [5];
- BE homogeneity volume $\propto \mathrm{d}N_{\rm ch}/\mathrm{d}\eta$ [6];

- BE decoupling time $\propto (\mathrm{d}N_{\mathrm{ch}}/\mathrm{d}\eta)^{1/3}$ [6].

It is assumed that the average number of participants is the same from 2.76 to 39 TeV. Note that the values measured at 2.76 TeV are reported without experimental uncertainties and are intended only for comparison.

The second part of Table 2 reports simple estimates of the energy density, initial temperature and minimum Bjorken x, using:

- $\varepsilon = \frac{1}{c\tau}\frac{1}{\pi R_A^2}\mathrm{d}E_{\mathrm{T}}/\mathrm{d}\eta$;
- $T = (\varepsilon\,(30/\pi^2)/n_{\mathrm{d.o.f.}})^{1/4}$, using the Stefan-Boltzmann relation with three quark flavours ($n_{\mathrm{d.o.f.}} = 47.5$);
- $x_2(y, Q^2) = Q\,\exp(-y)/\sqrt{s_{\mathrm{NN}}}$.

Table 2. Pb–Pb collisions at 2.76, 5.5 (extr) and 39 (extr) TeV.

Quantity	Pb–Pb 2.76 TeV	Pb–Pb 5.5 TeV	Pb–Pb 39 TeV
$\mathrm{d}N_{\mathrm{ch}}/\mathrm{d}\eta$ at $\eta = 0$	1600	2000	3600
Total N_{ch}	17000	23000	50000
$\mathrm{d}E_{\mathrm{T}}/\mathrm{d}\eta$ at $\eta = 0$	2 TeV	2.6 TeV	5.8 TeV
BE homogeneity volume	5000 fm^3	6200 fm^3	11000 fm^3
BE decoupling time	10 fm/c	11 fm/c	13 fm/c
T at $\tau = 1$ fm/c	280 MeV	300 MeV	365 MeV
ϵ at $\tau = 1$ fm/c	12 GeV/fm^3	16 GeV/fm^3	35 GeV/fm^3
x_2 at $y = 0$ vs. Q^2	$Q\,(\mathrm{GeV})\,4 \times 10^{-4}$	$Q\,(\mathrm{GeV})\,2 \times 10^{-4}$	$Q\,(\mathrm{GeV})\,3 \times 10^{-5}$
x_2 at $y = 4$ vs. Q^2	$Q\,(\mathrm{GeV})\,8 \times 10^{-6}$	$Q\,(\mathrm{GeV})\,4 \times 10^{-6}$	$Q\,(\mathrm{GeV})\,6 \times 10^{-7}$
x_2 at $y = 6$ vs. Q^2	$Q\,(\mathrm{GeV})\,1 \times 10^{-6}$	$Q\,(\mathrm{GeV})\,5 \times 10^{-7}$	$Q\,(\mathrm{GeV})\,8 \times 10^{-8}$

3. Some useful cross sections

Figure 1 from Ref. [7] shows the energy dependence for some cross sections for pp collisions.

References

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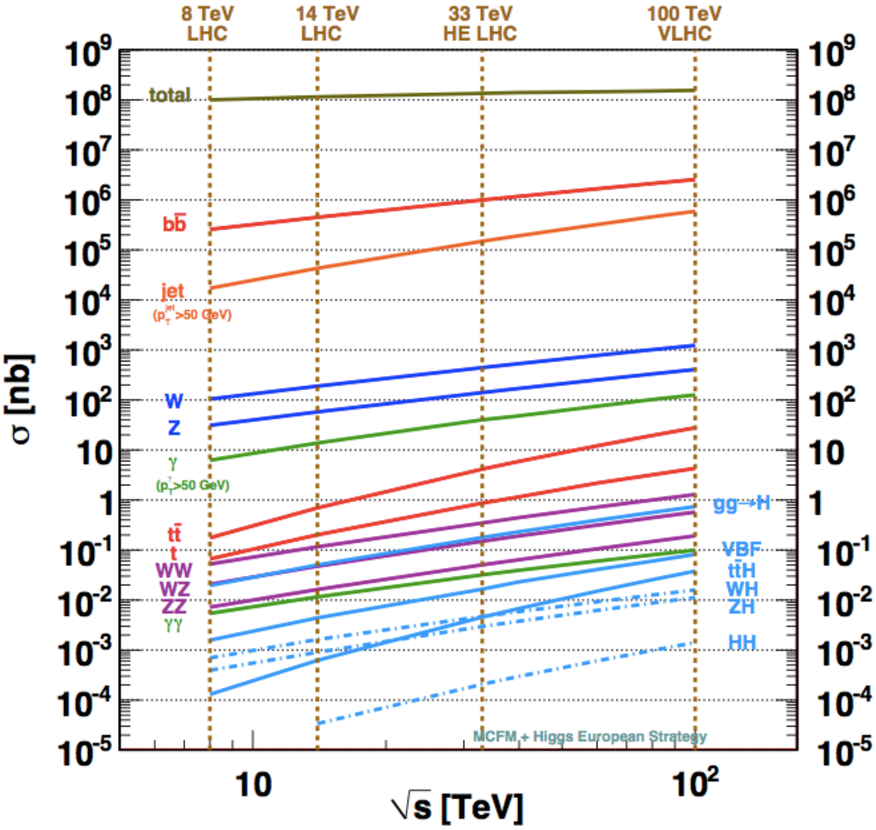

FIGURE 1. Cross sections for several processes in pp collisions as a function of $\sqrt{s}$ [7].