Case study - conceptual design of a hadron collider

- Make a green field design
- Be creative ! (but be prepared to defend your design and sell it to your colleagues)
- If you are uncertain or need additional information: ask
- Make sure you benefit from lectures, tutors and lecturers (and information you find elsewhere).

For a particle physics experiment design a machine with the specifications:

**Fundamental requirement:**
Produce $1.0 \times 10^6$ events with top-quarks per year (precision tests of standard model)

**Beam quality:**
Momentum spread $\frac{\Delta p}{p} \leq 0.3 \times 10^{-4}$. Bunch length not larger than 0.1.
Pile up should not be more than 2 per bunch crossing
Total cross section for $pp$ or $p\bar{p}$ (your choice) collisions $\approx 100$ mb (weak energy dependence)

Assume top quark mass 175 GeV/c$^2$, the top production cross section as a function of $\sqrt{s}$ (measurement and model) should be taken from the figure below (for the energy of your choice).
**Technical constraints:**
The length of the machine (whatever type) must not exceed 30 km
Optimistic 80% effective running time, i.e. for luminosity production
Total beam energy should not exceed 0.5 GJ and total beam current smaller than 1 A
Dipole magnets (if any) are normal conducting (with maximum field of 1.8 T)
Think of a possible injector chain consistent with your design

************************************************************************************************

**Hints for this exercise:**

- Prepare a conceptual design for the collider with a realistic parameter set, i.e.
  - Basic parameters: machine and particle type, beam energy, geometry (1 or 2 rings, what are the implications ?)
  - Luminosity (assume constant during operation), intensity, number of bunches, required emittance
  - Optics considerations: propose realistic optics parameters and contemplate about a lattice
  - Collective effects: space charge, beam-beam (keep below maximum value)
  - RF frequency, estimate r.m.s. bunch length , transition energy, ramping time
  - Synchrotron radiation, i.e. energy loss etc.
- Propose the necessary injector chain (multi-stage system)
  - The concept and design will be driven by the parameters of the collider
  - Type of accelerator and parameters (size, injection, extraction energies, field, RF and harmonic numbers), discuss superconducting versus normal conducting technology for the magnets.