LHC as a Heavy-Ion Collider

An update

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I-LHC Project

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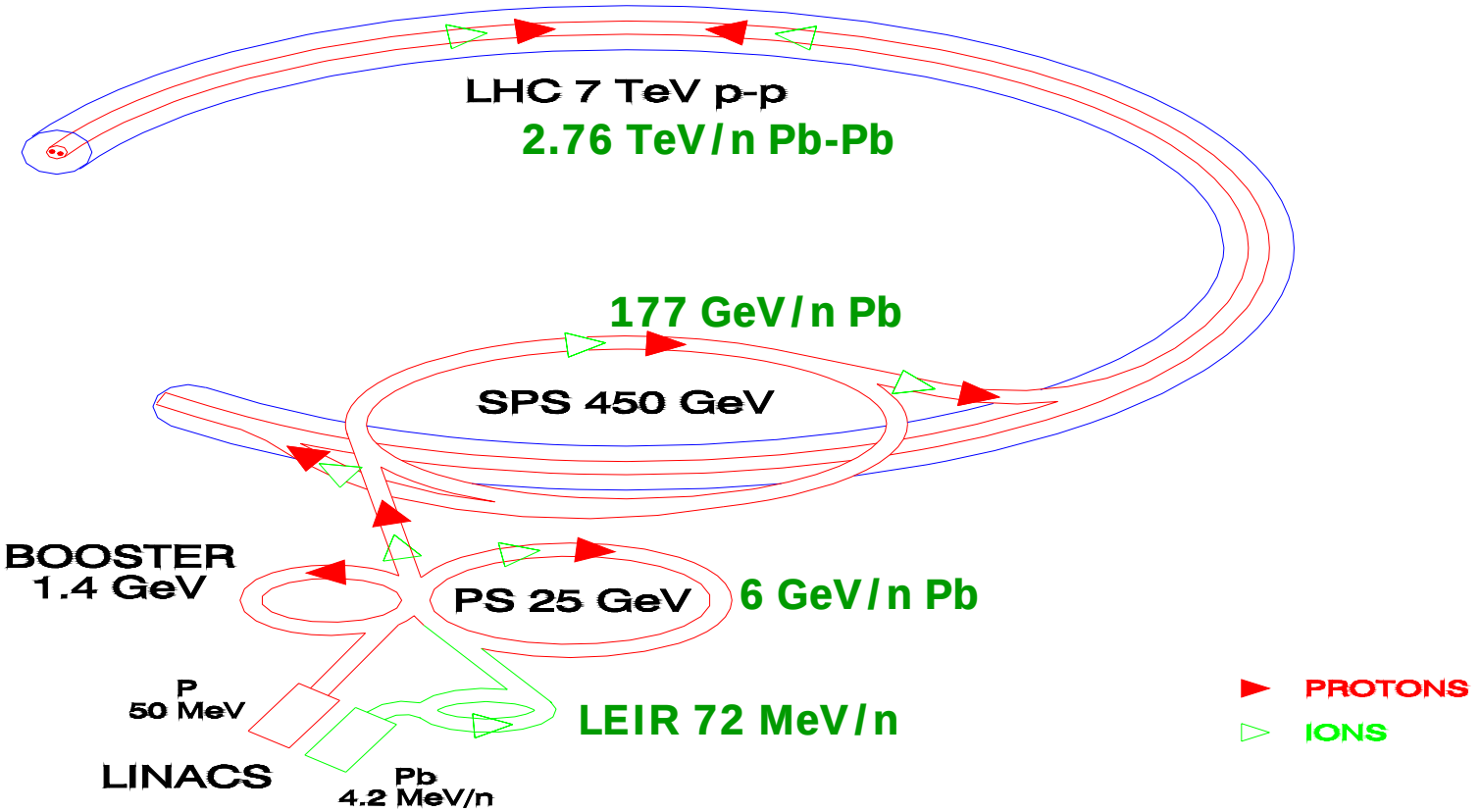
Presented by Bolek Wyslouch

The LHC Injector Chain - Schematic

Not to scale



LHC Pb Injector Chain: Key Parameters for luminosity 10^{27} cm^{-2} s^{-1}

	ECR Source → Linac 3	4 → LEIR →	PS	13.12.8 → SPS	12 → LHC
Output energy	**2.5 KeV/n**	**4.2 MeV/n**	**72.2 MeV/n**	**5.9 GeV/n**	**177 GeV/n**	**2.76 TeV/n**
^{208}Pb charge state	**27+**	**27+ → 54+**	**54+**	**54+ → 82+**	**82+**	**82+**
Output Bρ [Tm]		2.28 → 1.14	4.80	86.7 → 57.1	1500	23350
bunches/ring			2 (1/8 of PS)	4 (or 4x2)[4]	52,48,32	592
ions/pulse	9 10^9	1.15 10^9 [1])	9 10^8	4.8 10^8	≤ 4.7 10^9	4.1 10^{10}
ions/LHC bunch	**9 10^9**	**1.15 10^9**	**2.25 10^8**	**1.2 10^8**	**9 10^7**	**7 10^7**
bunch spacing [ns]				100 (or 95/5)[4]	100	100
ε*(nor. rms) [μm][2]	**~0.10**	**0.25**	**0.7**	**1.0**	**1.2**	**1.5**
Repetition time [s]	0.2-0.4	0.2-0.4	3.6	3.6	~50	**~10'fill/ring**
ε_{long} per LHC bunch[3]			0.025 eVs/n	0.05	0.4	1 eVs/n
total bunch length [ns]			200	3.9	1.65	1

Stripping foil

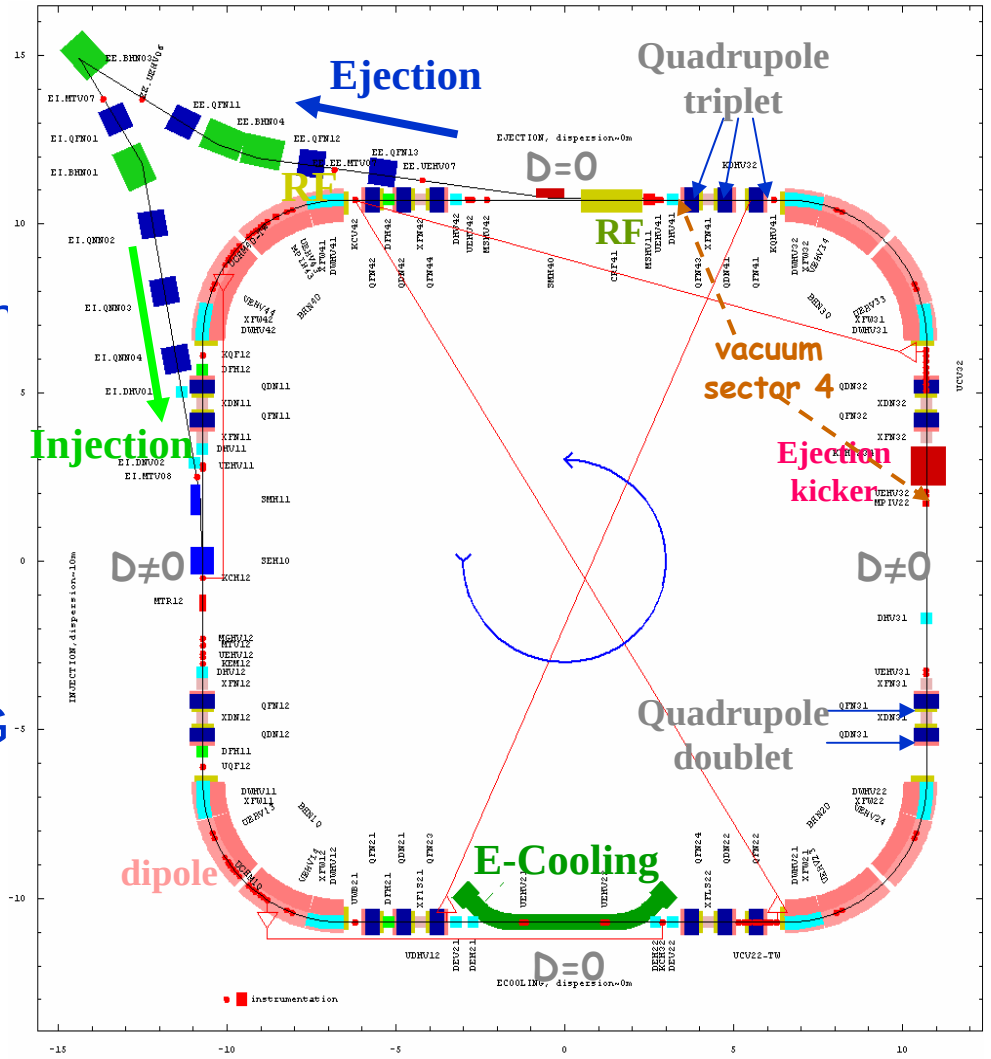
[1] 50 eμA$_e$ x 200 μs Linac3 output after stripping

[2] Same physical emittance as protons,

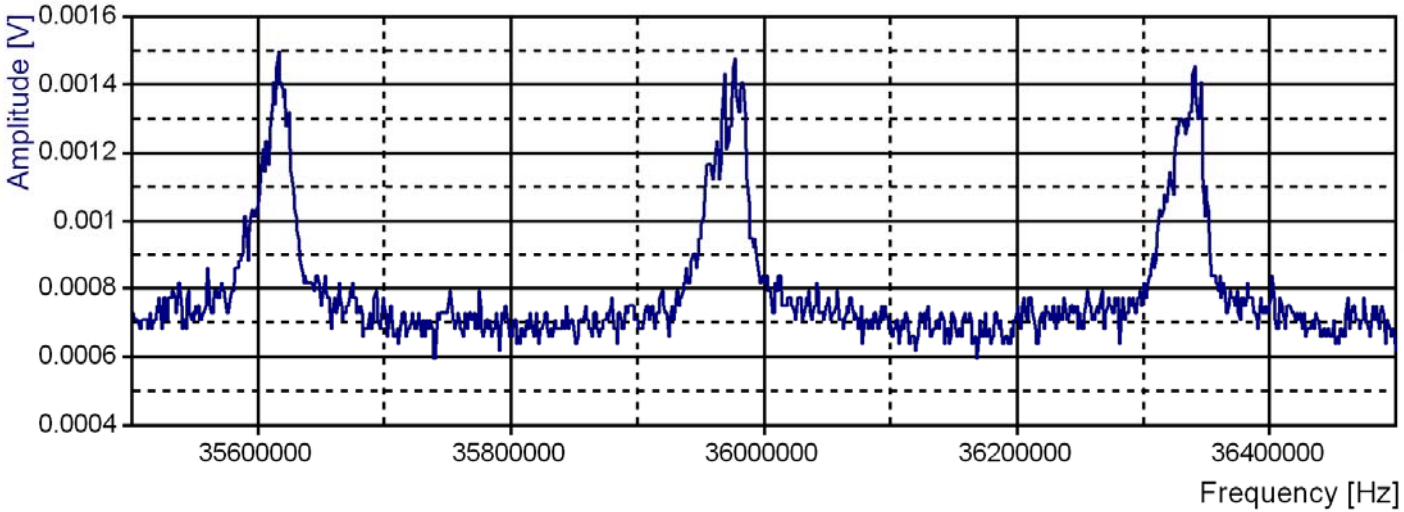
$$\varepsilon^* \equiv \varepsilon_n = \sqrt{\gamma^2 - 1}\,\varepsilon_{x,y}$$ is □ invariant in ramp.

LEIR (Low-Energy Ion Ring)

- Prepares beams for LHC using electron cooling
- circumference 25m (1/8 PS)
- Multiturn injection into horizontal+vertical+longitudinal phase planes
- Fast Electron Cooling : Electron current from 0.5 to 0.6 A with variable density
- Dynamic vacuum (NEG Au-coated collimators, scrubbing)

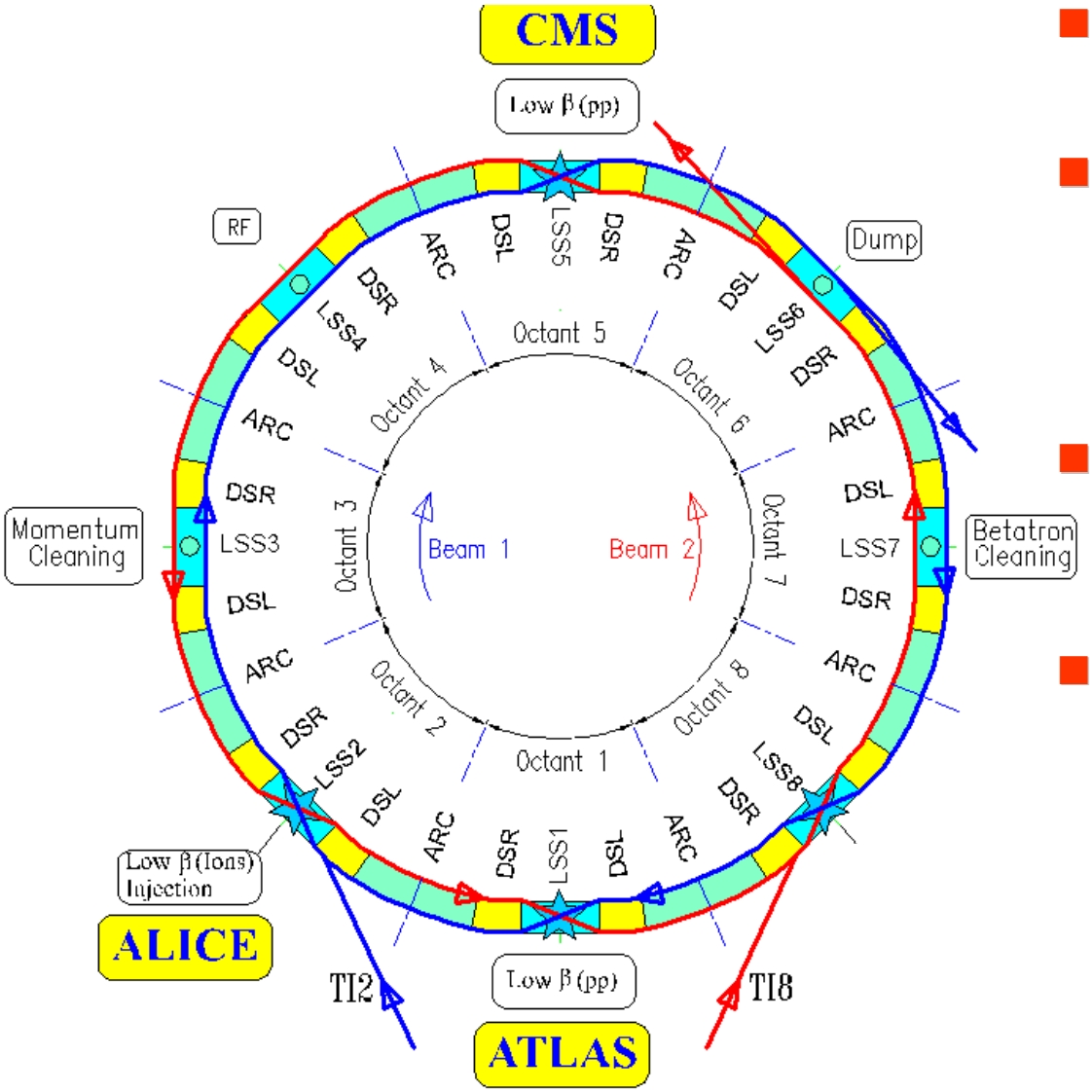


First Circulating Beam in LEIR



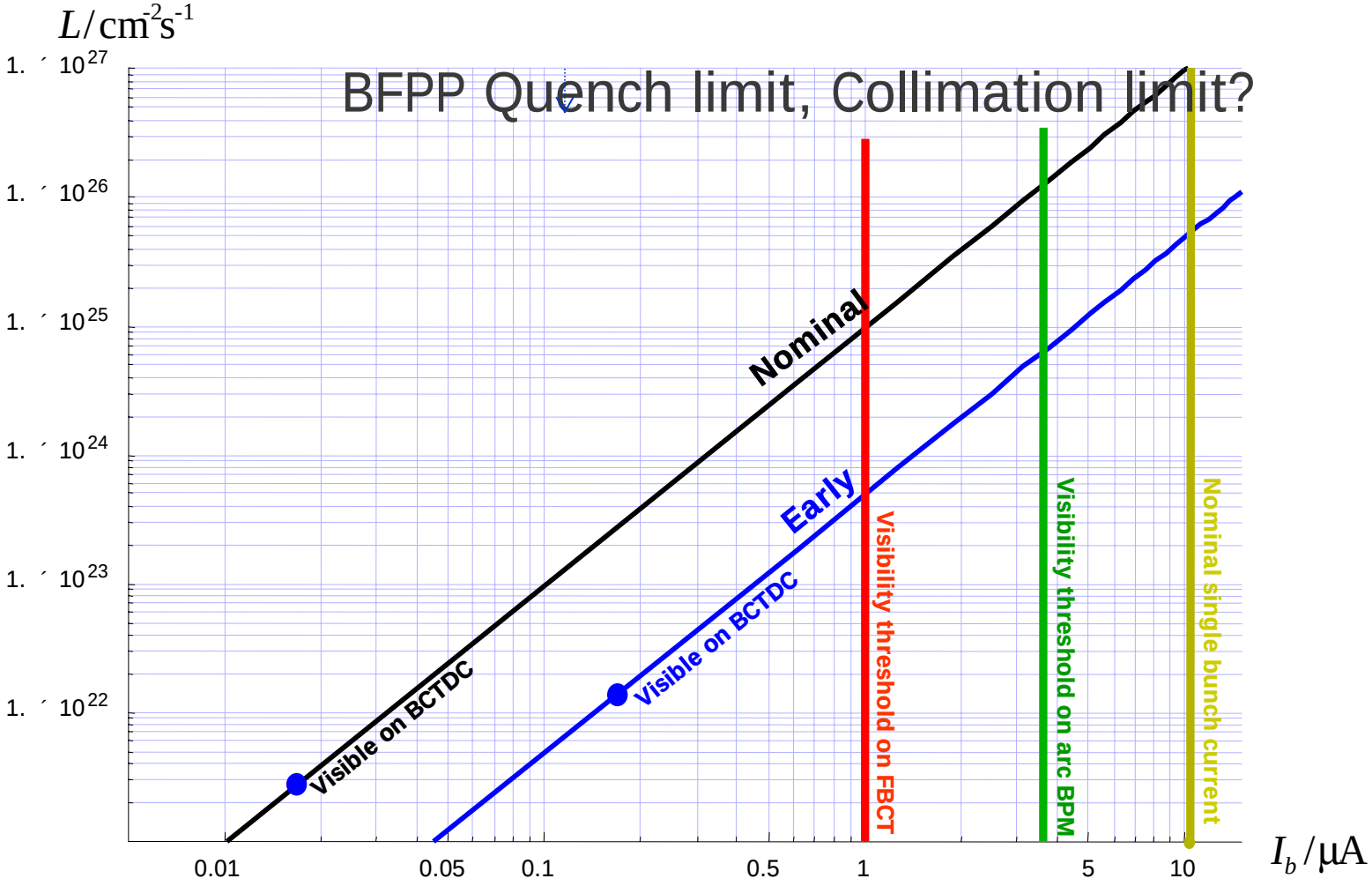
- Schottky spectrum of the circulating beam of O^{4+} ions in LEIR on October 11, 2005.
- Three harmonics of the revolution frequencies around the 100th are shown.
- Beam made full turn of the ring immediately on first injection.
- Circulated for up to 200 ms.
- Vacuum leak problem since then ...

LHC Collisions with Lead Ions



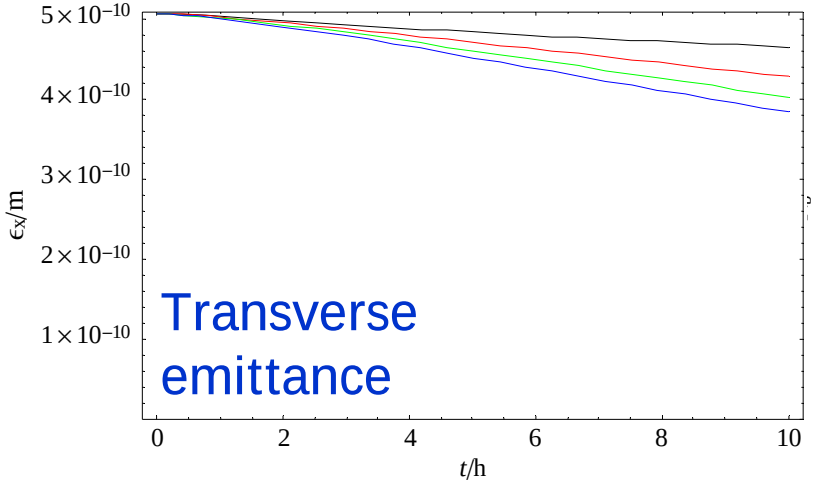
- $^{208}Pb^{82+}$-$^{208}Pb^{82+}$ collisions
- CM energy 1.15 PeV with nominal dipole field.
  Beam energy 2.76 A TeV
- ALICE detector specialises in heavy ion physics
- CMS and ATLAS are also interested in heavy ion physics

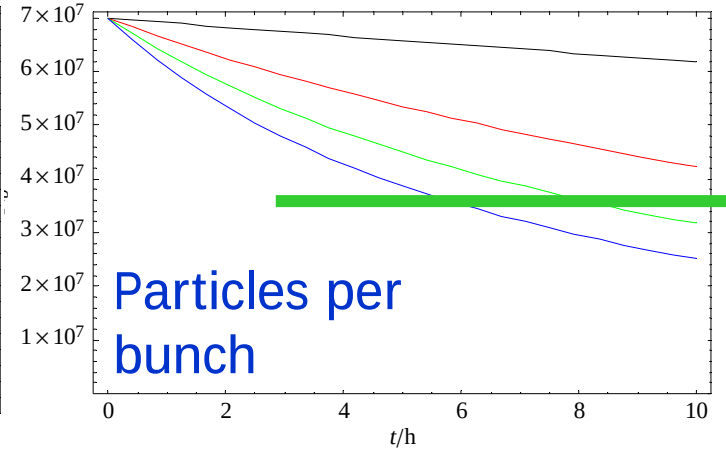
Operational parameter space with lead ions



Thresholds for visibility on BPMs and BCTs.

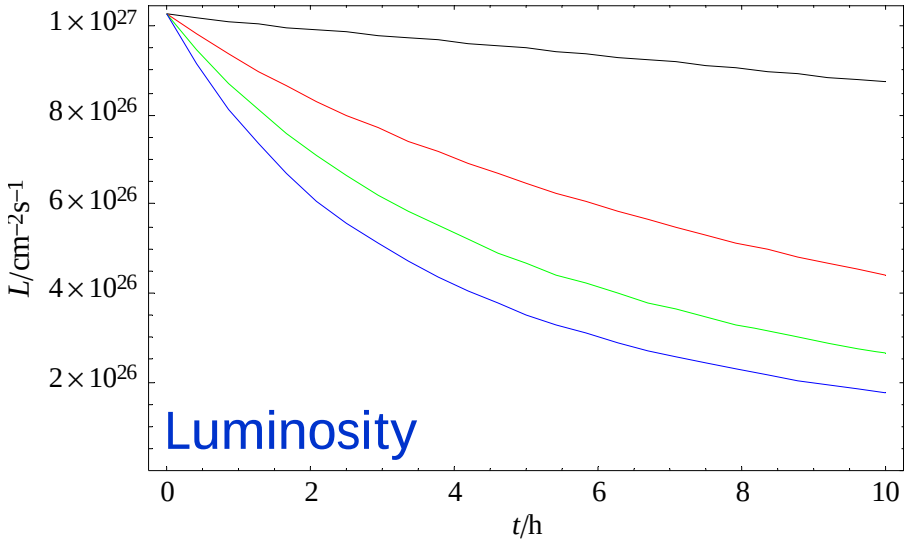
Luminosity evolution: Nominal scheme





No. of experiments: $n_{exp} = 0, 1, 2, 3$

An "ideal" fill, starting from design parameters giving nominal luminosity.



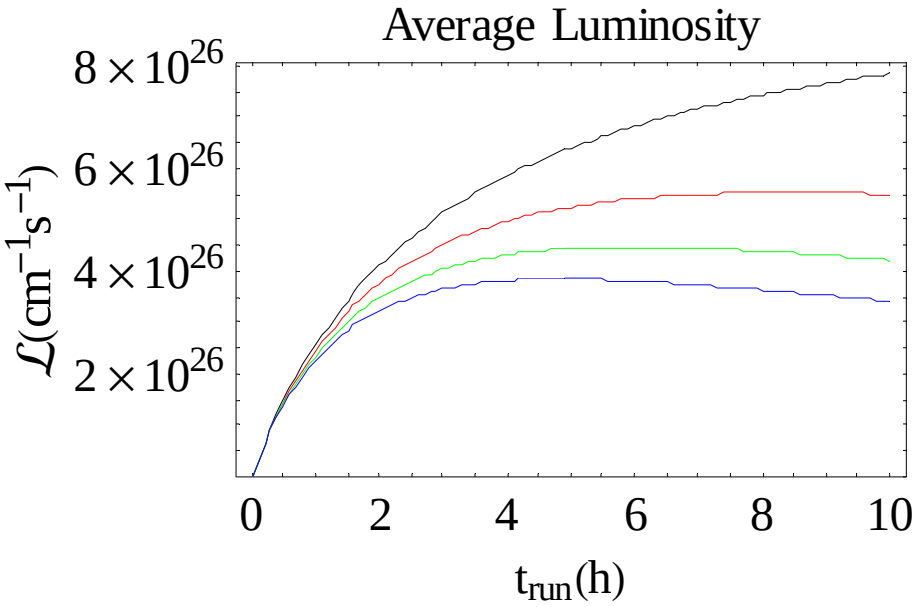
Increasing number of experiments reduces beam and luminosity lifetime.

Example: average luminosity

Average luminosity depends strongly on time taken to dump, recycle, refill, ramp and re-tune machine for collisions.

Average luminosity with 3h turn-around time, in ideal fills starting from nominal initial luminosity.

Maximum of curve gives optimum fill length.



No. of experiments: $n_{exp} = 0, 1, 2, 3$

Beams will probably be dumped to maximise average $\mathcal{L}$ **before** BPM visibility threshold is reached.

I-LHC Planning

- Baseline: Lead-Lead collisions
  - "Early Pb Scheme" – much easier to achieve – for 2008 (and 2009?)
    - Allows study of performance limitations.
  - "Nominal Pb Scheme" by 2009 (or 2010?)
    - Pb-Pb is perceived as posing the most difficult accelerator physics problems
- Future "upgrades" not in Baseline:
  - p-Pb collisions under study
    - Effects of revolution frequency difference at injection expected to be *much weaker* than at RHIC
  - lighter ion-ion collisions (e.g. Ca, Ar, O, ...) appear possible without major upgrades, to be studied.

Summary

- Operation of LHC with lead ions limited by new effects, qualitatively different from protons
  - Several effects important around level of design luminosity (uncertainties in their estimation but some recent grounds for optimism)
- Restricted to a narrow operational range of parameters below the nominal luminosity
- “Early scheme” will allow relatively safe commissioning, access good initial physics
- Study of p-Pb mode has begun, looks promising
- LEIR commissioning has started with some success and some setbacks …