



LHeC Ring-Ring option for electron-proton and electron-nucleus collisions

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Nominal Pb-Pb collision parameters

		Injection	Collision
Beam parameters			
Lead ion energy	[GeV]	36900	574000
Lead ion energy/nucleon	[GeV]	177.4	2759.
Relativistic “gamma” factor		190.5	2963.5
Number of ions per bunch		$7. \times 10^7$	
Number of bunches		592	
Transverse normalized emittance	[μm]	1.4 ^a	1.5
Peak RF voltage (400 MHz system)	[MV]	8	16
Synchrotron frequency	[Hz]	63.7	23.0
RF bucket half-height		1.04×10^{-3}	3.56×10^{-4}
Longitudinal emittance (4σ)	[eV s/charge]	0.7	2.5 ^b
RF bucket filling factor		0.472	0.316
RMS bunch length ^c	[cm]	9.97	7.94
Circulating beam current	[mA]	6.12	
Stored energy per beam	[MJ]	0.245	3.81
Twiss function $\beta_x = \beta_y = \beta^*$ at IP2	[m]	10.0	0.5
RMS beam size at IP2	μm	280.6	15.9
Geometric luminosity reduction factor F^d		-	1
Peak luminosity at IP2	[$\text{cm}^{-2}\text{sec}^{-1}$]	-	$1. \times 10^{27}$



Nominal Pb-Pb, lifetime parameters

		Injection	Collision
Interaction data			
Total cross section	[mb]	-	514000
Beam current lifetime (due to beam-beam) ^a	[h]	-	11.2
Intra Beam Scattering			
RMS beam size in arc	[mm]	1.19	0.3
RMS energy spread $\delta E/E_0$	[10^{-4}]	3.9	1.10
RMS bunch length	[cm]	9.97	7.94
Longitudinal emittance growth time	[hour]	3	7.7
Horizontal emittance growth time ^b	[hour]	6.5	13
Synchrotron Radiation			
Power loss per ion	[W]	3.5×10^{-14}	2.0×10^{-9}
Power loss per metre in main bends	[Wm ⁻¹]	8×10^{-8}	0.005
Synchrotron radiation power per ring	[W]	1.4×10^{-3}	83.9
Energy loss per ion per turn	[eV]	19.2	1.12×10^6
Critical photon energy	[eV]	7.3×10^{-4}	2.77
Longitudinal emittance damping time	[hour]	23749	6.3
Transverse emittance damping time	[hour]	47498	12.6
Variation of longitudinal damping partition number ^c		230	230
Initial beam and luminosity lifetimes			
Beam current lifetime (due to residual gas scattering) ^d	[hour]	?	?
Beam current lifetime (beam-beam, residual gas)	[hour]	-	< 11.2
Luminosity lifetime ^e	[hour]	-	< 5.6



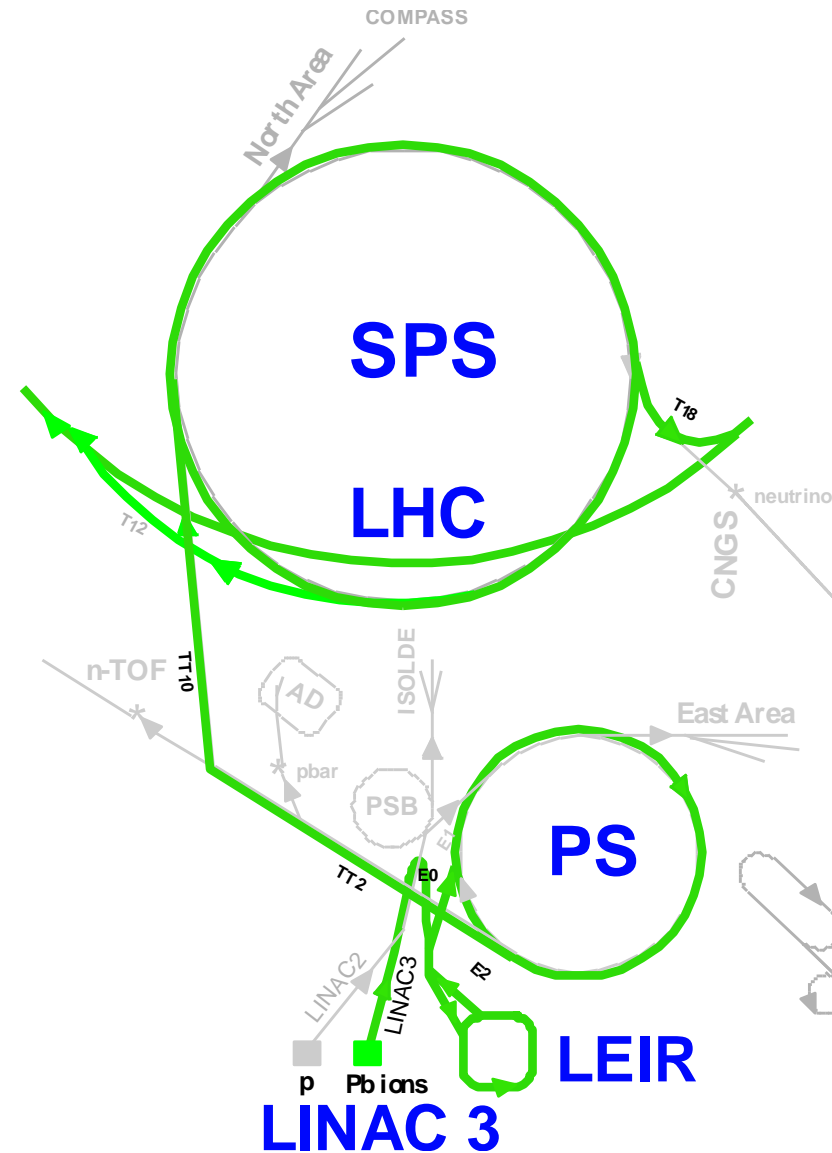
Electron-nucleus (e-A) collisions

- The LHC will operate as a nucleus-nucleus (initially Pb-Pb) collider
 - Physics programme is expected to include:
 - Pb-Pb at $\sqrt{s_{NN}} = 5.5 \text{ TeV}$
 - p-Pb at
 - A-A where A may be Ca, O, ...
- Natural possibility of colliding electrons with nuclei
- Requires maintenance of LHC ion injector complex through to the time of operation of LHeC
 - Pursuing all stages of the LHC programme will in any case take several years
 - Upgrades to injectors ? Source, eg, EBIS ?



LHC Ion Injector Chain

- **ECR ion source (2005)**
 - Provide highest possible intensity of Pb^{29+}
- **RFQ + Linac 3**
 - Adapt to LEIR injection energy
 - strip to Pb^{54+}
- **LEIR (2005)**
 - Accumulate and cool Linac3 beam
 - Prepare bunch structure for PS
- **PS (2006)**
 - Define LHC bunch structure
 - Strip to Pb^{82+}
- **SPS (2007)**
 - Define filling scheme of LHC





Emittance tuning

■ Phase advance choice

- Phase advance per cell is NOT a good *operational* tuning knob for emittance
- Can be changed occasionally but this requires some “re-commissioning” (LEP experience)
- Limited possibilities for damping partition
- Wigglers are a better choice for tuning
 - LEP experience shows that they *can* be operated as transparent/orthogonal knobs for damping time and emittance, useful up to ~ 50 GeV
 - Must be well-made and come with automatic compensation of optical perturbations (c.f. LEP “damping” and “emittance wigglers” vs. cheap LEP “polarization wigglers”)



Summary

- Propose LHeCe arc cells with half length of LHC cells
 - Facilitate integration (?)
- Phase advance choice ($90^\circ, 60^\circ$)
 - Good experience with dynamic aperture at LEP
 - Momentum compaction a bit small
 - Aperture $\sim 2/3$ that of LEP
- Quadrupole length is important
 - Damping partition variation
 - Operation with variable hadron energy/species
- Operation as e-Pb collider $L > 10^{29} \text{ cm}^{-2}\text{s}^{-1}$
 - Lighter ions possible
 - Maintain/upgrade ion injector complex