RCS Cost Estimate

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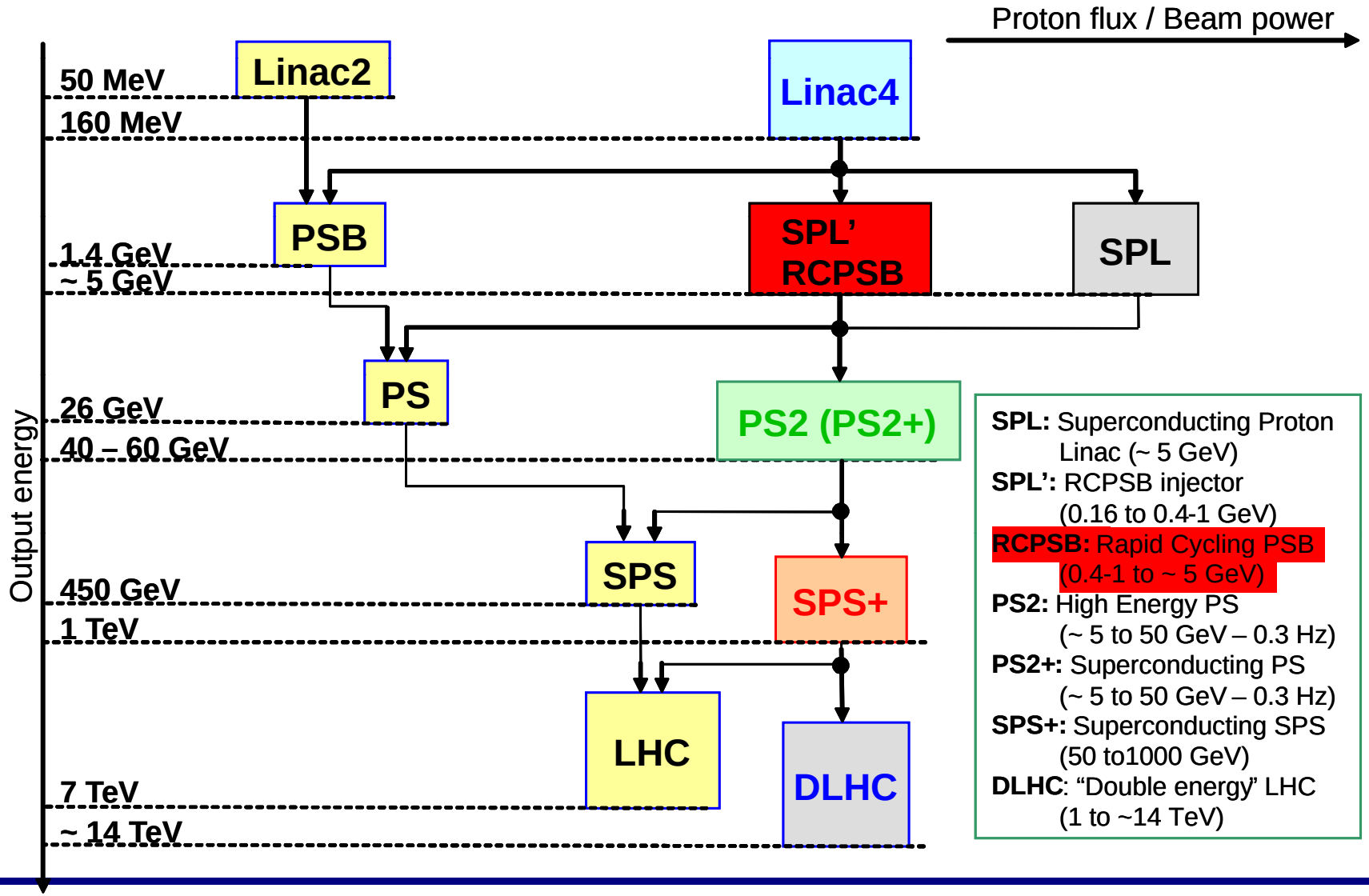
Introduction



CERN RCS vs Beta-beam RCS (i)

- **Study of a CERN RCS for proton chain in first half 2007 for comparison with SPL as PS injector.**
  - **Machine based on Beta-beam RCS**
  - **Lattice and layout optimisation by A. Tkatchenko, A. Lachaize**
- **Particles and energy range**
  - **CERN: protons 400 MeV to 4 GeV**
  - **Beta-beam baseline: 100 MeV/n to 3.5 GeV**
- **Magnetic rigidities**
  - **CERN: 3.18 Tm to 16.1 Tm**
  - **Beta-beam: 2.66 Tm (18Ne) or 4.44 Tm (6He) to 14.5 Tm**
- **Machine lengths**
  - **CERN: 269.2 m (1/5 of PS2, with PS2 = 15/7 PS)**
  - **Beta-beam: 251.3 m (2/5 of PS)**

CERN RCS vs Beta-beam RCS (ii)

- **Filling scheme for downstream machine.**
  - **CERN: h=1 operation to fill 15 bunches in PS2.**
  - **Beta-beam: h=1 operation to fill 20 bunches in PS.**
  - **Repetition rate for both machines 10 Hz.**
- **RF systems**
  - **CERN: h=1 main system and h=2 system for bunch flattening**
  - **Beta-beam: h=1 system (0.5 to 1.2 MHz) 100 kV**
    - Both cases “low frequency’ tuneable systems
- **Injection parameters**
  - **CERN: ~100 μs H- pulse length (charge exchange injection)**
  - **Beta-beam: 50 μs pulse length (multi-turn injection).**
- **Extraction parameters**
  - **Fast extraction in both cases.**

Magnet system estimate

Magnet Costs (215 magnets)				
Magnets for RCS	***Installed magnets***	***Spare magnets***	***Total number***	**Costs (kCHF)**
Bending Magnets	72	7	79	3963
Quadrupoles	48	5	53	1944
Correctors	48	5	53	1260
Sextupoles	27	3	30	950
Bus bars (dipoles and quads)				980
Testing, installation and commissioning				1150
Total	**195**	**20**	**215**	**10247**

The magnet supply includes: raw materials, design (magnetic + mechanical), manufacturing, production follow-up, testing at the supplier, supports, alignment targets, covers, water hoses from the tunnel to the magnets, electrical cables from the tunnel to the magnets, water cooled bus bars, spare magnets, transport (internal + external), acceptance tests at CERN, installation, commissioning.

The magnet supply does not incude: vacuum chambers, electrical and water supply to the tunnel, interlock system, manpower for survey, equipment and manpower for magnetic measurements at CERN, transport vehicles.

- **Note that dipole estimate is based on a H-type cross-section**
- **Power consumption and water cooling requirements:**
  - Main dipoles 2 MW
  - Main quadrupoles 0.5 MW

Main power converters estimate (i)

- **Main converter layout follows new PS converter**
  - **Capacitive energy storage included in converter architecture**
    - Freely programmable converter (no resonant supply)
    - No compensation network needed
    - Modular “Lego” type approach for converter design (6 kA / 10 kV)
- **Main bending magnet design to fit converter design**
  - **Main bending circuit 5.6 kA / 28 kV could be realised by three “standard” converter modules, one per arc (three-fold symmetry)**
- **Main quadrupole magnets less critical with lower stored energy**

Main power converters estimate (ii)

Power Converter Cost				
Power converters for RCS	***Installed units***	***Spare units***	***Total number***	**Costs (kCHF)**
Main Bending Magnets	3	1	4	22592
Quadrupoles	2	1	3	6480
Correctors	48	5	53	1060
Sextupoles	27	3	30	900
Total	**80**	**10**	**90**	**31032**

- **No cost for infrastructure included (electricity, cooling ventilation and civil engineering included)**
- **Water cooling requirements:**
  - Main dipole converters 315 kW
  - Main quadrupole converters 120 kW
- **Civil engineering requirements:**
  - Indoor surface dipole and quadrupole converters: 1000 m2
  - Outdoor surface (container and transformer): 200 m2

RF system estimate

- **Estimate based on classical solution**
  - **Ferrite loaded RF system**
  - **Beta-beam parameters very similar to PS Booster first harmonics system (500 kHz to 1.6 MHz) and LEIR system, recently rebuilt.**
    - The overall cost (cavities, amplifier, etc) averages to 100 CHF/V.
- **Beta-beam RF requirement 100 kV installed voltage**
  - **10 MCHF global cost for ferrite loaded RF system**
  - **Typical gradient in classical system 5 kV/m**
    - Requires 20 m of straight section, compatible with RCS layout.
  - **Estimate for finemet system with higher gradients missing**
    - See with GSI, JParc .
  - **No estimate for transverse/longitudinal feedback systems.**
- **Maximum beam power ~20 kW**
  - **Total installed electrical power 100 kW → water cooling load**

Injection and extraction elements

- **Multi-turn injection system**

Multi-turn injection system	Plane	B.dl [T.m]	τ rise/fall [us]	Aperture HxV [mm]	Cost [MCHF]
Injection septum + converter	H	0.50	1000	110 x 80	1,5
Electrostatic septum + HV supply	H	0.075	dc	130 x 80	2,3
Painting kickers (4) + converters	H	0.025	50-300	160 x 80	1,4
Total					5,2

- **Extraction system based on simplified geometry**
  - **Single kicker with 7.5 mrad and single septum with 160 mrad.**

System	Plane	B.dl [T.m]	τ rise/fall [us]	Aperture HxV [mm]	Cost [MCHF]
Extraction septum + converter	H	2.64	1000	110 x 80	2,1
Extraction kicker + PFN	H	0.12	0.1	110 x 80	5,4
Total					7,5

  - **Spare magnets (1 per type) included in estimate**

Vacuum system estimate

- **Assumed classical system**
  - **Thin metallic dipole chamber, no ceramic chambers for the 10Hz option eventually with ribs.**
  - **Non bake-able system with pressure ~10^{-9} mbar**
- **Scaling from recent PS2 estimate**
  - **Based on number of magnets (prop. to chambers, bellows, etc)**
  - **RCS ~ 1/3rd of components but more complex dipole chamber**
    - PS2 10 MCHF
    - RCS 4 MCHF

Control system and beam diagnostics estimates

- **Controls System: Scaling from PS Booster machine**
  - **Number DSCs Booster * 1.5 * 15 kCHF = 30 * 15 k = 0.45 MCHF**
  - **Interior of DSCs (50 k / DSC) = 30 * 50 k = 1.5 MCHF**
  - **Diagnostics systems (200 Oasis a 2kCHF) = 0.4 MCHF**
  - **Timing + cabling + field bus total 1.5 MCHF**
    - 4 MCHF

- **Beam diagnostics system**
  - **Conventional system without special equipment**
  - **Typical cost around 7-8% of total machine cost.**
    - Estimate 5 MCHF

RCS overall cost for machine

Equipment	Cost [MCHF]
Magnet system	11.0
Power converters	31.0
Radio frequency	10.0
Injection extraction	13.0
Vacuum	4.0
Controls	4.0
Beam diagnostics	5.0
Total	**78.0**
Total incl. 30% contingency	**100.0**

Next steps

- **Estimates for civil engineering**
  - **Accelerator building (tunnel or covered) + access shafts**
  - **Surface buildings**
- **Estimates for technical infrastructure**
  - **Electrical infrastructure**
    - 2 MW main magnets + 0.5 MW main converters + 0.1 MW RF
    - 1.4 MW for other facilities + CV installation + buildings
    - Total 4 MW installed power (without transfer lines)
  - **Water cooling**
    - 4 MW installed capacity demineralised water
  - **Ventilation**
    - Assume 3% of installed power air i.e. ~100 kW ventilation cooling

Summary

- **First cost estimate for RCS machine components**
  - **100 MCHF capital cost**
- **Missing items**
  - **Civil engineering estimate**
  - **Cooling and ventilation estimate**
  - **Transferline and integration into PS complex**
- **How to address personnel estimates**
  - **Compare to EURISOL approach**