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SUPERCONDUCTING SPS (scSPS) as 1.3 TeV injector for FCC

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Outline

- Why scSPS?
- scSPS
- Optics and Magnets
- Insertions
- Transfer lines
- Conclusion and outlook to CDR

Why scSPS?

The LHC is complex and demanding, and likely expensive to operate and maintain in comparison to other options.

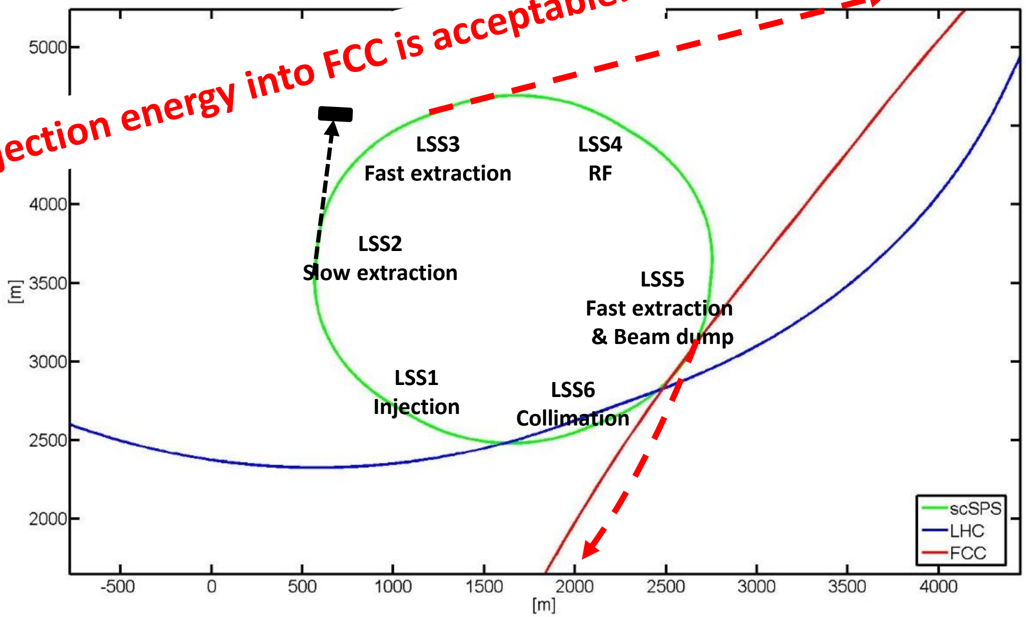
→What are the other options?

- 450 GeV injection from present SPS?
- New accelerator in the FCC tunnel?
- Re-use the SPS tunnel and design a new accelerator!

scSPS – Layout

- Keep SPS geometry (6 LSS).
- Replace SPS by a new superconducting single aperture machine.
- Reasonable **magnetic field at 6 T → Extract at 1.3 TeV** - **fast ramping**.
- Magnets, beam transfer and RF seem feasible. Collimation is challenging.
- SPS energy swing increases from ~20 to ~50.

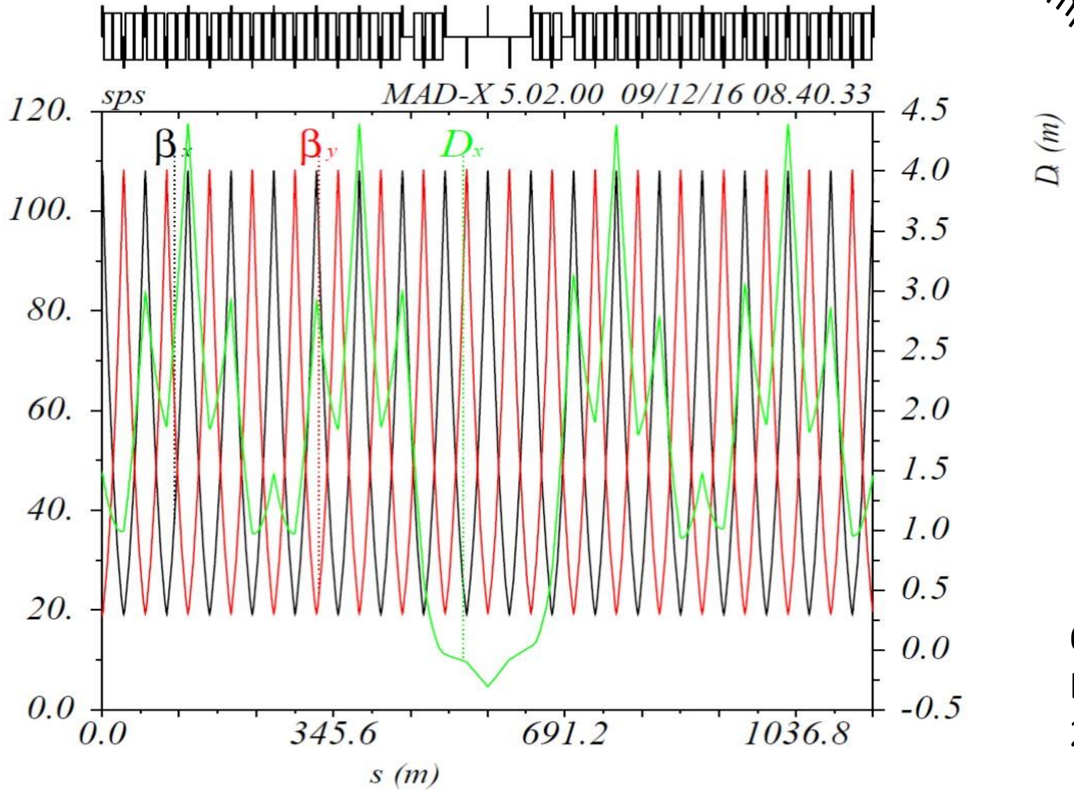
Interesting option, if 1.3 TeV injection energy into FCC is acceptable.



Main parameters

Parameter	Unit	Value
Injection energy	GeV	26
Extraction energy	GeV	1300
Dipole field at injection	T	0.12
Maximum dipole field	T	6
Ramp rate	T/s	0.35 – 0.5
Cycle length	min	1
Max. number of bunches / cycle		640
Number of injections		8 (80b)
Number of protons / bunch		≤ 2.5E11
Number of extractions per cycle		4 x 160 b
FCC filling time	min	34 – 40
Stored beam energy	MJ	≤ 33

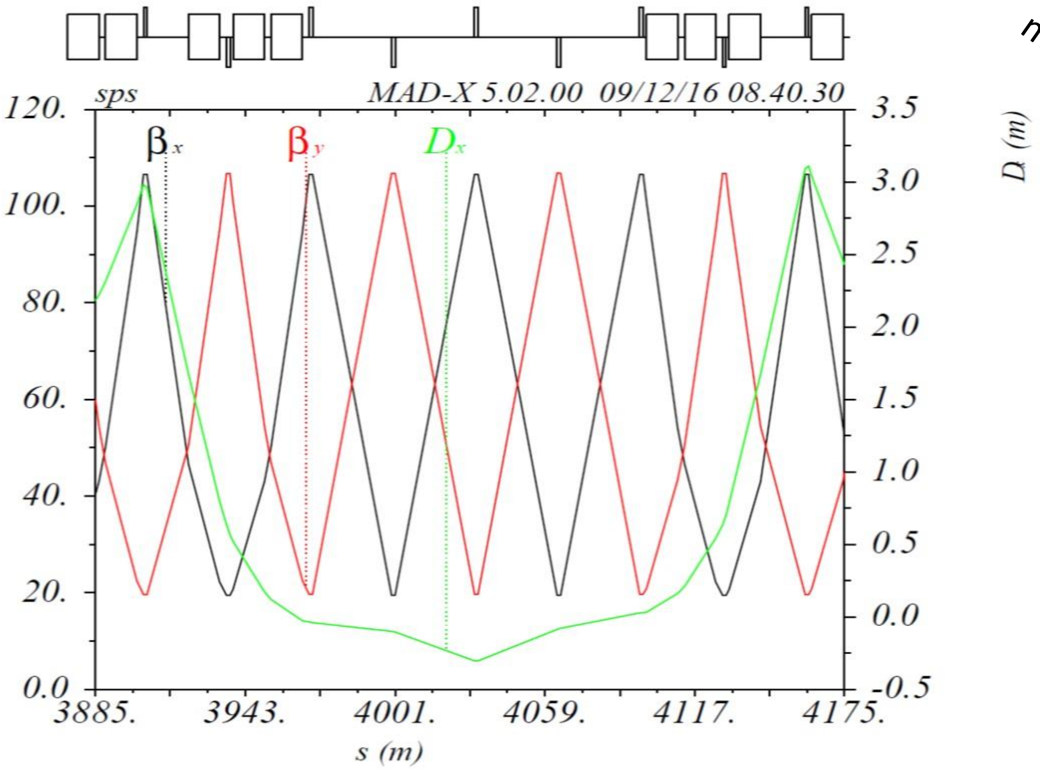
Optics – arc and straight section



Comparable to SPS optics.

64 m cell length
Dipole filling factor: 0.75.
2.65 m free space per half cell.

Straight section and DS



DS as in the present SPS with missing bend scheme.

Optics parameter and magnet aperture

Parameter	Unit	Value
Max. beta $\beta_{x,z}$	m	107
Max. dispersion D_x	m	4.3
Orbit + alignment tolerance $O_{x,y}$	mm	2.5
Injection oscillation	mm	1.5
Emit[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
A_x / A_y	mm	76 / 69
Coldbore inner diameter	mm	80

Presentation: Alexandre Kovalenko:
Design of 6 T superconducting dipole for SPS upgrade

$$A_{x,y}/2 = |O_{x,y}| + |I_{x,y}| + 10\sqrt{1.21\beta_{x,y}\epsilon_{x,y}} + 1.1|D_{x,y}|\delta p/p$$

2.5 mm 1.5 mm 10 σ

Summary magnet parameters

Parameter	Unit	Value
Dipoles		
Max. field dipole	T	6
Magnetic length dipole	m	12.12
Ramp rate	T/s	0.35 – 0.5
Cold bore inner diameter	mm	80
Number of dipoles		372
Quadrupoles		
Magnetic length quadrupole	m	1.35
Cold bore inner diameter	mm	80
Pole tip field	T	5.85
Gradient	T/m	67
Number of quadrupoles		216

Needs new access shafts

Injection insertion

Injection kickers	26 GeV	Septa	26 GeV
Bdl [Tm]	0.26	Bdl [Tm]	1.9
Kick angle [mrad]	3	Kick angle [mrad]	22
Rise time [ns]	200-250	Blade thickness [mm]	7
HW length [m]	10	HW length [m]	10

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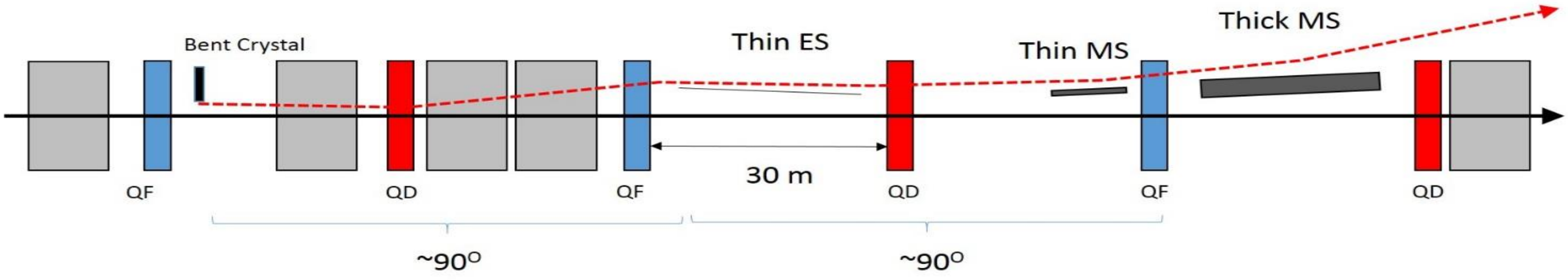
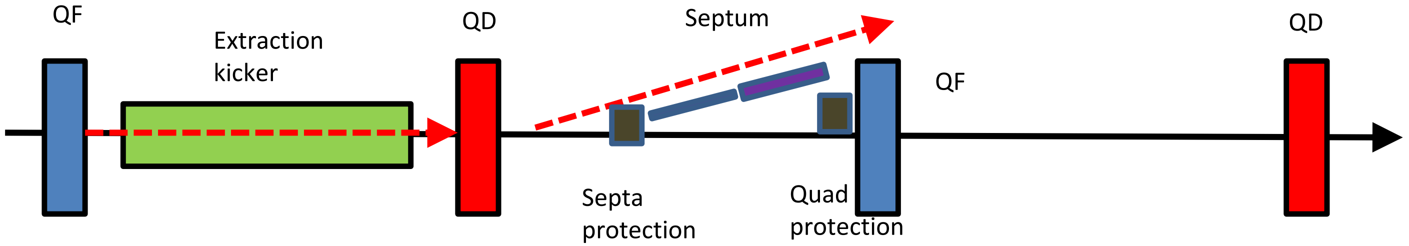
Slow extraction

Non-resonant transverse excitation – use of a bent crystal.
Losses during slow extraction, need of additional absorbers and septa protection to be studied.



- Assumed beam characteristics of the injector complex after LIU upgrade.
- 2.2 μm emittance with 2.5E11 protons/bunch.
- 2E5 spills per year (200 days), 5E13 protons/spill → 1E19 protons/year (comparable with present North Area parameters).
- Losses and interplay with collimation system to be studied.

Fast extraction to FCC

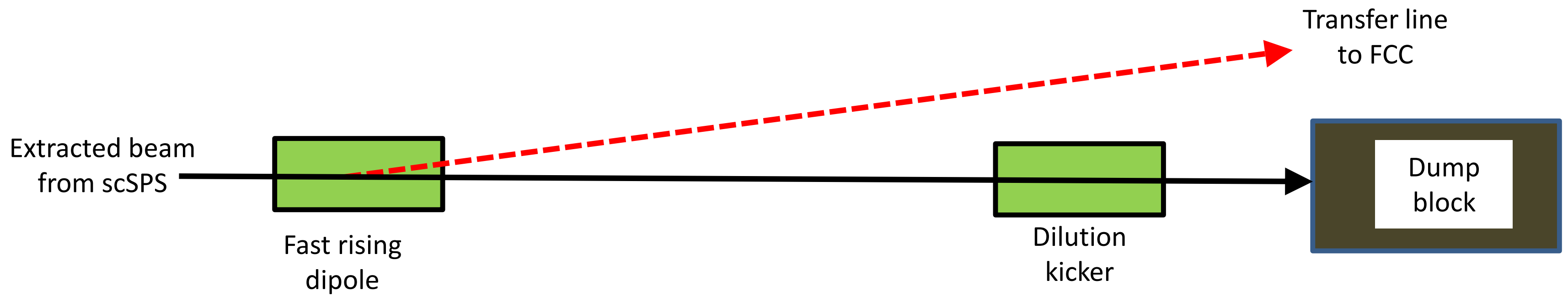


Presentation: D. Woog:
Magnetic core and semiconductor switch characterisation for an Inductive Adder kicker generator.
Wednesday afternoon.
Poster: A. Chmielinska:
Solid state marx generators for use in the injection kickers of the FCC

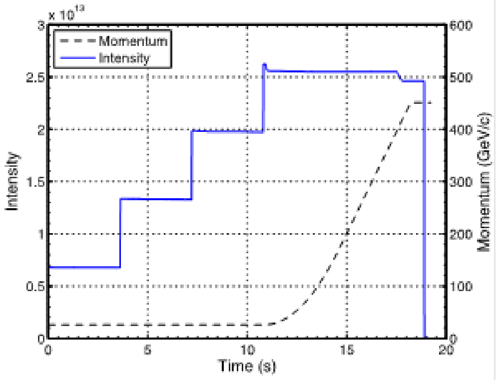
Septa	1300 GeV
Bdl [Tm]	20
Kick angle [mrad]	4.6
Blade thickness [mm]	7
HW length [m]	20

Beam dump and fast extraction insertion

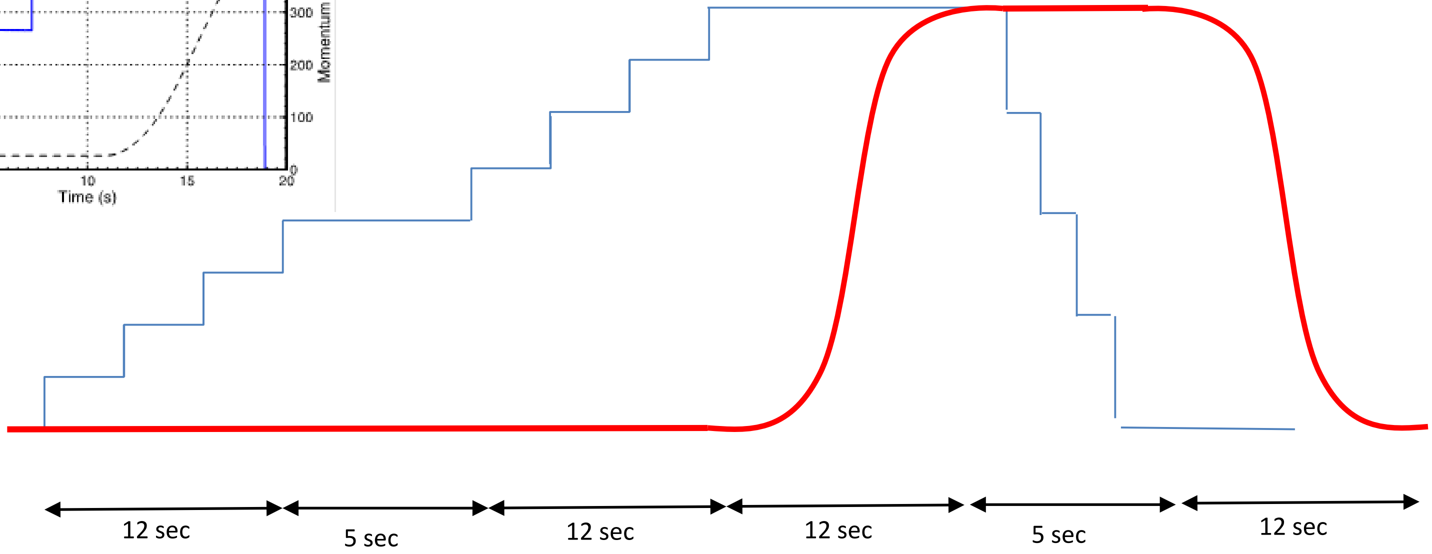
External dump line needed.
Combined external beam dump (26 GeV – 1.3 TeV) and fast extraction to FCC – complex system.
Dilution kicker system needed.
Extraction protection needs detailed study.



scSPS cycle for FCC filling



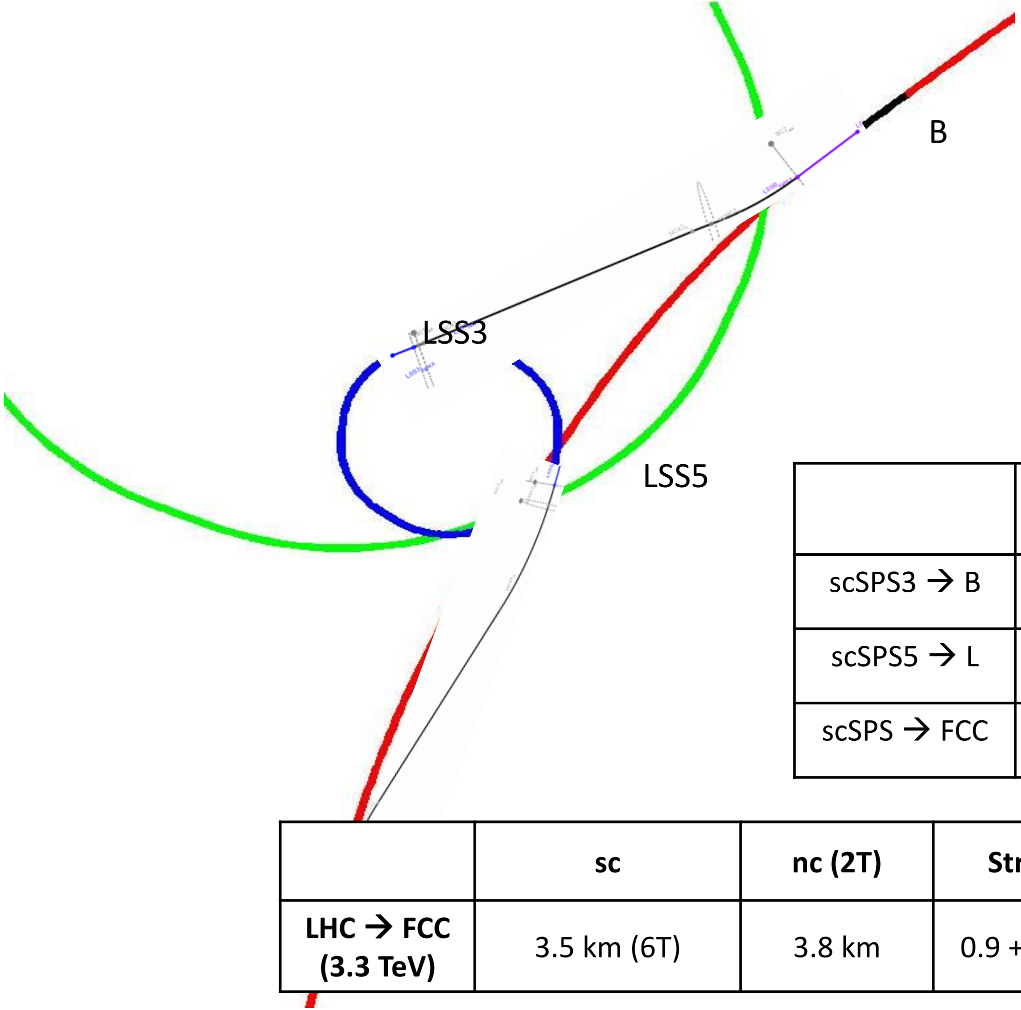
First cycle (3 min): 1b, 1b, 12b, 12b, 12b, 12b to check FCC TL and orbit.
34 cycles with 640 b each → max 10880 b
→ **37 min to fill FCC.**



Cycle length: 1 min

scSPS → FCC

scSPS3 → FCCB
scSPS5 → FCCL



	nc (2T)	Straight	Total length
scSPS3 → B	1.3 km	3 km	4.3 km
scSPS5 → L	2.5 km	2.8 km	5.3 km
scSPS → FCC	3.8 km	5.8 km	9.6 km

	sc	nc (2T)	Straight	Total length
LHC → FCC (3.3 TeV)	3.5 km (6T)	3.8 km	0.9 + 3.6 km	11.8 km

Summary - Why scSPS?

- **New accelerator – will be designed to serve as injector** for FCC, HE-LHC and Fixed Target up to 1.3 TeV**.**
  - Layout defined.
  - Low complexity.
  - High degree of flexibility.
  - Insensitive to configuration changes - multiple users.
- **Lower po**
- **Reduced complexity** of the FCC injector chain (4 instead of 5 injectors to FCC).
- Transfer lines to FCC can be designed shorter and with **nc magnets**.
- **Higher number of bunches** can be transferred safely.
- **Higher energy** for fixed target areas and test facilities like HiRadMat.
- **HE-LHC could profit**:
  - Lower energy swing.
  - Beneficial for impedance.
  - Aperture at injection.

Can the collider accept an injection energy of 1.3 TeV?

To be studied for the CDR

- Further studies for collimation and machine protection.
- Optimize optics studies.
- Transfer line design (optics / collimators).
- Methods for slow extraction.
- Losses during slow extraction process.
- Complexity of combined beam dump and extraction.

<u>Beyond CDR:</u>

- Study quench behaviour of the magnets.
- Hardware design for the different insertions.
- Study of septa protection.
- …

Thank you!