Super Proton-Proton Collider

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Snowmass Agora on Future Colliders: Circular pp and ep Colliders

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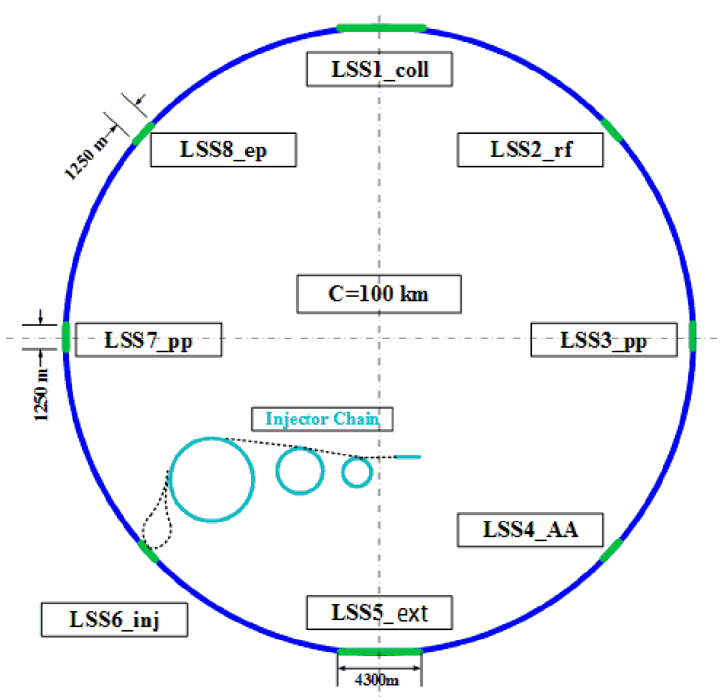
Outline

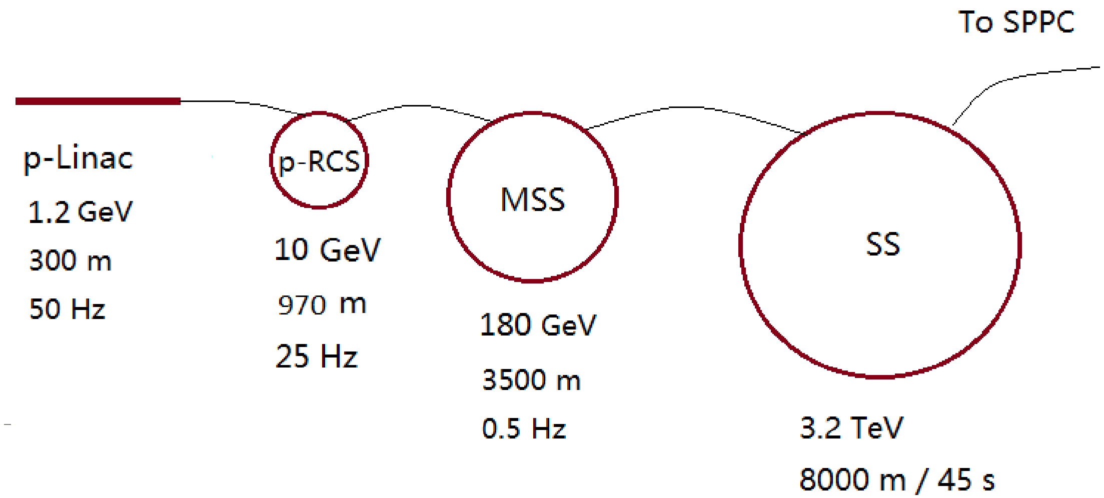
- Brief description on SPPC
- Key technologies and maturity
- How to reach the CoM energy goal
- Costs and cost risks
- Key beam physics challenges
- Ideal timeline
- Key parameters and input to the "ITF Table"

Brief description on SPPC

- SPPC (Super Proton-Proton Collider) is the second stage of the CEPC-SPPC project promoted by China
  - CEPC built first, as the precision measurements (Higgs, W, Z, and ttbar)(CoM: 240 GeV, 160 GeV, 90 GeV, 360 GeV)
  - SPPC the second (~100 TeV), focusing on energy-frontier research (BSM physics but also rare Higgs channels)
  - ep collision is also under consideration
- CEPC and SPPC will share the same collider tunnel of 100 km
  - Totally different machines
  - SPPC is a two-ring collider (CoM: 125 TeV), fed by an injector chain of four accelerators

SPPC Layout





p-Linac: proton superconducting linac

p-RCS: proton rapid cycling synchrotron

MSS: Medium-Stage Synchrotron

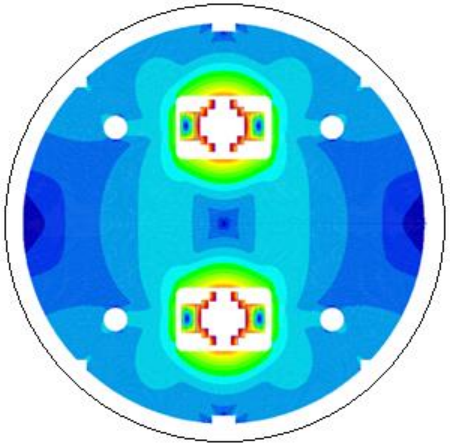
SS: Super Synchrotron

- Two main detectors: @LSS3 and LSS7
- LSS1: collimation (CEPC detector)
- LSS2: rf stations
- LSS5: ejection (CEPC detector)
- LSS6: injection
- LSS4/LSS8: reserved for AA and ep

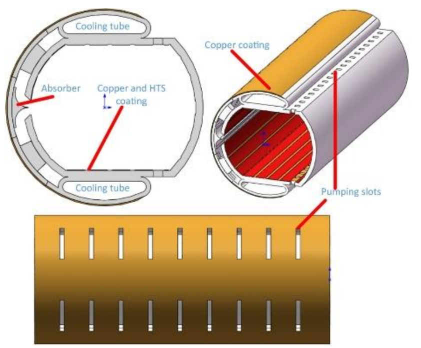
- Ion beams possible
- Beams from injector accelerators for various physics programs

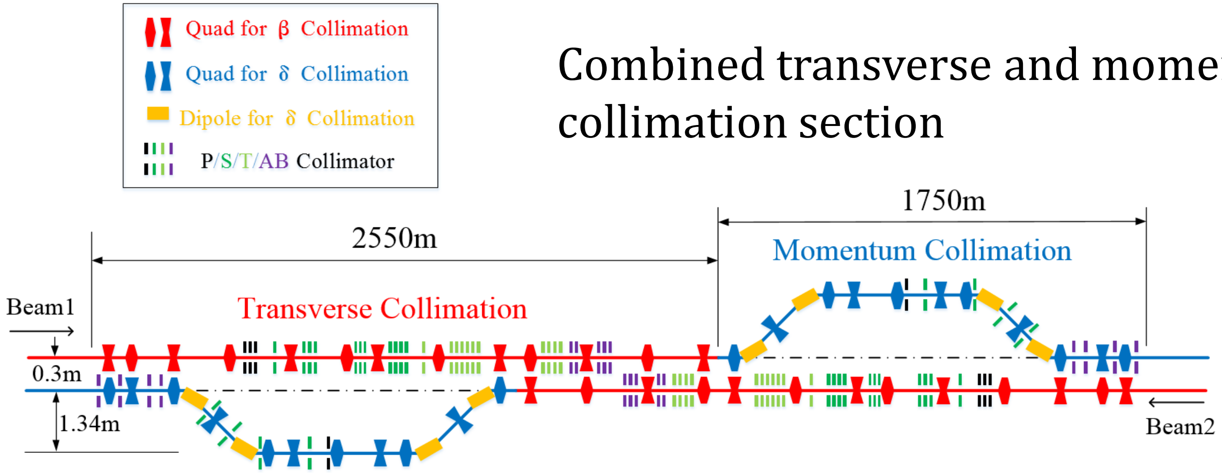
Key technologies and maturity

- High-field superconducting magnets - dipole and quadrupoles with high field quality: the most important technology, for both their availability and cost effectiveness
  - 20-T magnets far beyond state-of-the-art, needing long-term R&D efforts (15-20 years)
  - HTS or hybrid (LTS+HTS) magnets more promising in reaching 20 T
  - HTS especially iron-based (IBS) magnets much more cost effective than Nb_3Sn, but less mature



- Beam screen and vacuum: to prevent synchrotron radiation (~2.2 MW per beam) onto the cold vacuum chamber (2-4 K)
  - Beam structure : tackling vacuum pumping, electron cloud alleviation, low coupling impedance and mechanical sustaining of magnet quenches
  - Conceptual solutions available, far from maturity, needing serious R&D efforts





Combined transverse and momentum collimation section

- Collimators: materials sustaining very high irradiation from primary protons and secondary particles, low impedance, needing significant improvements from LHC, modest maturity
- Crab cavities: high field, low impedance and compact space, will base on the experience at HL-LHC, modest maturity
- Injection/extraction magnets: powerful kickers with fast rise/fall time, superconducting septum magnets, modest maturity
- Efficient cryogenic plant and transmission: very high cryogenic heat load (magnets, beam screens, RF) ➔large contribution to total power consumption, modest maturity

How to reach the CoM energy goal

- Limitation factors to beam energy (62.5 TeV)
  - Circumference (~100 km)
  - Fields of magnets (~20 T)
  - Powerful injector chain (Energy gain in collider < 20, injection energy to ~3.2 TeV)
  - Luminosity: sacrifice of luminosity with higher beam energy due to rapid increase on SR power (burden on beam screen), ➔lower bunch population and luminosity

$$P \propto I_b \gamma^4$$

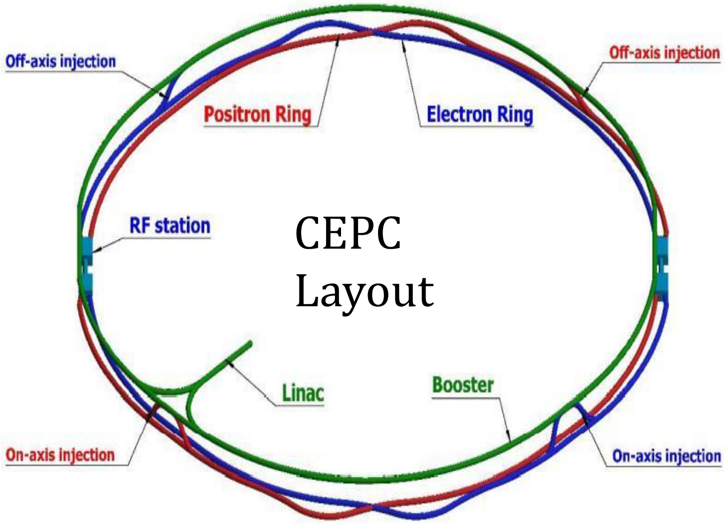
- Intermediate run (37.5 TeV)
  - For higher luminosity, studying rare Higgs channels etc.
  - Magnetic field: 12 T
  - Bunch population increased: $1.5*10^{11}$ (vs $0.4*10^{11}$)
  - Integral luminosity increased by a factor of about 3

Costs and cost risks

- Difficult to have cost estimate, high risk
  - Assuming the 100-km tunnel (CEPC) reused: modest civil modifications; all land reserved from CEPC; about 27 km new tunnels for SPPC injectors and transport lines
  - Large uncertainty in magnets: hopeful IBS successful, much cheaper than Nb_3Sn
  - Manpower in China will increase largely (a few times) if China will enter rich countries club in 20 years
  - Other key technologies successfully resolved
- We hope
  - SPPC construction cost be in the range of 10-15B US$ (2021)
- It is argued
  - SPPC construction will not start until key technologies available and cost affordable.

Key beam physics challenges

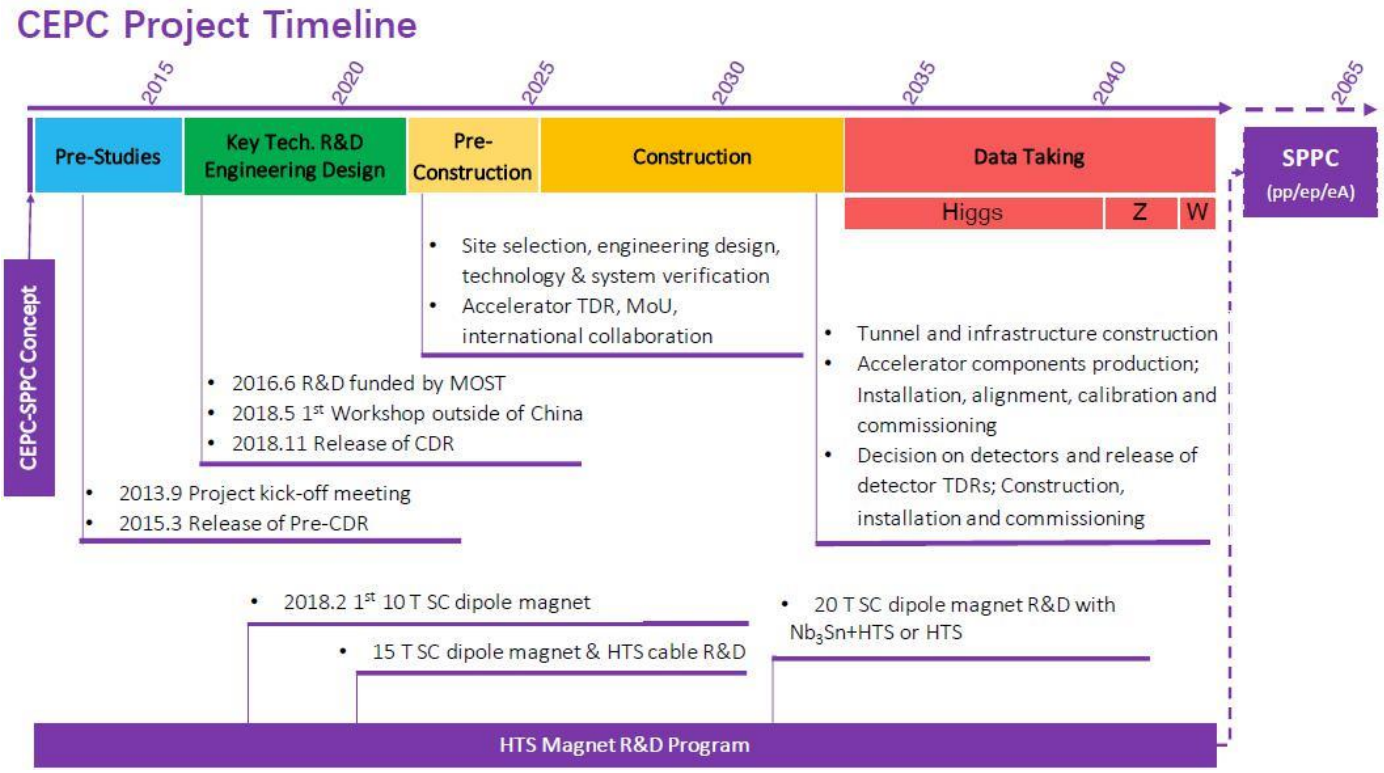
- Collider rings
  - Lattice: in particular IR regions, compatibility with CEPC
  - Beam-beam effects and luminosity leveling: push B-B parameters to the limit (with compensations) to increase luminosity



  - Collimation and beam abort: huge stored energy in beams and beam loss power when in collision, machine safety
  - Impedance and instabilities: difficult to manage impedance of 100 km ring, in particular beam screens, large number of collimators
- Injector chain
  - All high beam power machines (MW level, or stored energy in beam >50 MJ)
  - Producing the required beam properties for the collider rings: emittances, bunch population, bunch spacing, bunch trains, cycling period, etc.

Ideal timeline

- SPPC is the second stage of the CEPC-SPPC project, assuming
  - CEPC being approved and built within the next decade
  - 20-T magnets available and cost effective in 15-20 years
- SPPC study and construction
  - CDR (2030-2034), TDR (2035-2028), Construction (2042-2048)



Key parameters and input to the "ITF Table"

	SPPC
CoM Energy and upgrades (TeV)	125 (intermediate run: 75)
Peak luminosity (10^{34} $cm^{2}s^{-1}$)	13
IP difficulties	2 IP; dynamic beta*: 0.75-0.25 m; L*: 36 m; crab cavities; MDI: beam-loss background
Length of the facility (km)	~127
Length of new accelerators (km)	~127
Beam parameters challenges	Bunch: 0.4-1.5*10^{11}, 25 ns; Emit: 1.2 μm; I_b: 0.2-0.7 A
Special technologies	IBS magnets, beam-screen
R&D/validation (yrs needed);	>15 yrs (magnets)
Construction start year	2042
Cost	10-15B US$
Level of maturity	1: Significant R&D needed
Env. Issues: AC power, resources (Nb, LHe)	Order of 400 MW

Summary

- SPPC is the second stage of the CEPC-SPPC project, a discovery machine in energy frontier (125 TeV CoM), aiming for two decades from now
- Key technologies such 20-T magnets require long-term R&D efforts

Thanks for your attention!