SPPC Study Status

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Main topics

- Design goals
- Progress in preliminary conceptual design
- Studies on key technical issues
- Summary

DESIGN GOALS

SPPC Design Goal Evolution

- Pre-CDR
  - About 50 km in tunnel length, 20-T magnets to reach 70 TeV or above, high luminosity
  - Further development (together with CEPC): 61 km, longer long straight sections for collimation (partial double-ring for CEPC)
- CDR
  - 100-km tunnel
  - Different visions: 16T-100TeV, 20T-125TeV, 12T-75TeV/20T-125TeV
  - CDR SPPC design goals: First Phase: 12 Tesla, >70 TeV; Ultimate Phase: 20-24 Tesla, 125-150 TeV

SPPC main parameters

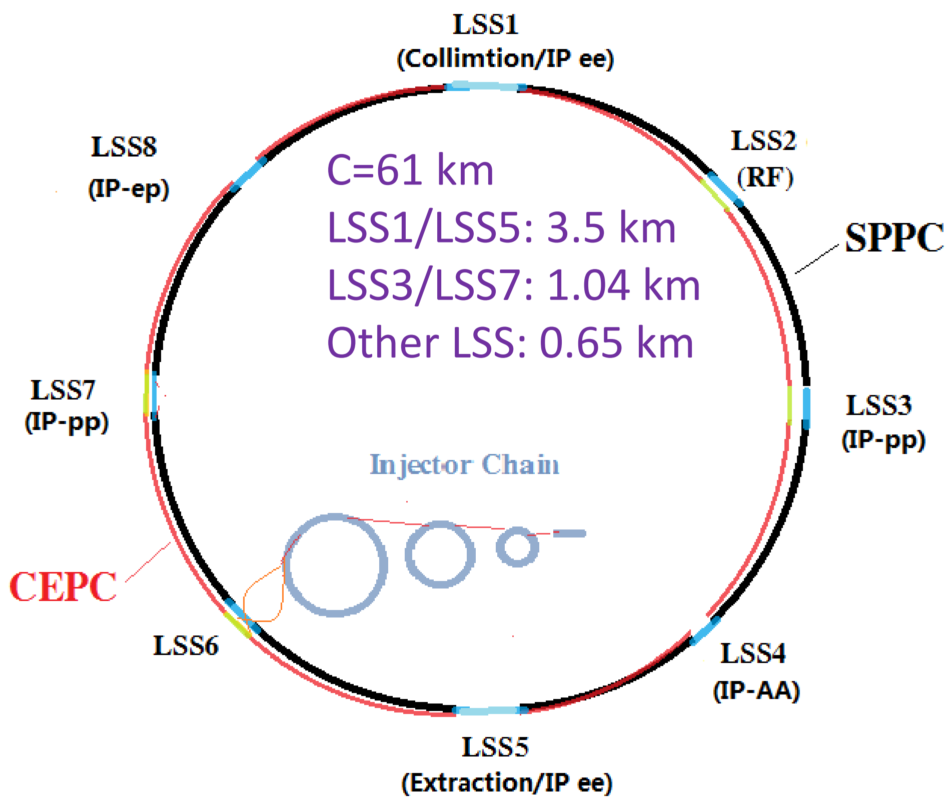
Parameter	Unit	Value		
		PreCDR	CDR	Ultimate
Circumference	km	54.4	100	100
C.M. energy	TeV	70.6	75	125-150
Dipole field	T	20	12	20-24
Injection energy	TeV	2.1	2.1	4.2
Number of IPs		2	2	2
Nominal luminosity per IP	$cm^{-2}s^{-1}$	1.2e35	1.0e35	-
Beta function at collision	m	0.75	0.75	-
Circulating beam current	A	1.0	0.7	-
Bunch separation	ns	25	25	-
Bunch population		2.0e11	1.5e11	-
SR power per beam	MW	2.1	1.1	-
SR heat load per aperture @arc	W/m	45	13	-

PROGRESS IN PRELIMINARY CONCEPTUAL DESIGN

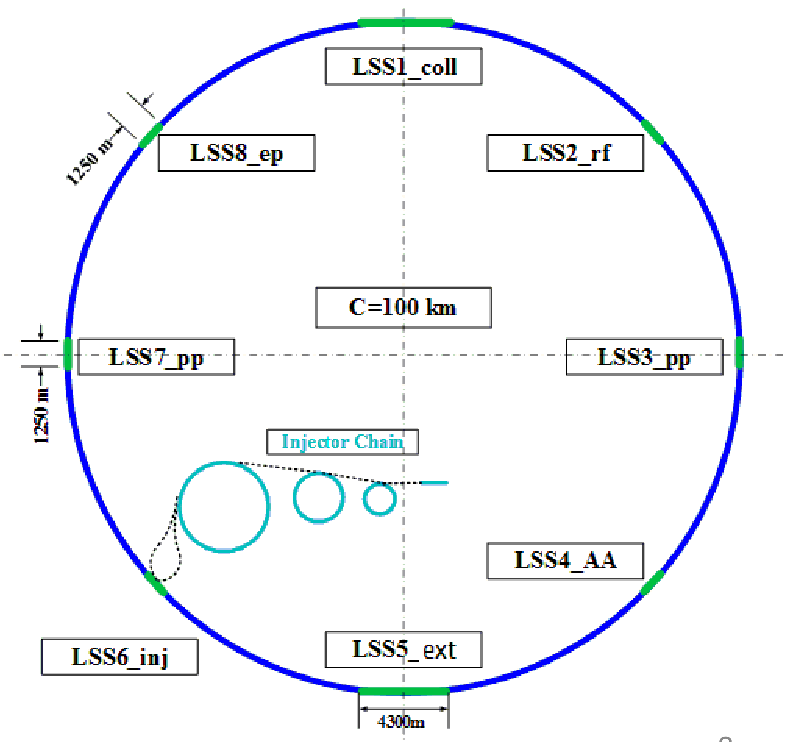
- Main working topics
  - General parametric design
  - Collider accelerator physics
    - Layout and lattice design
    - Luminosity leveling
    - Collimation
    - Beam-beam effects
    - Injection/extraction
    - Instabilities
    - Bunch filling schemes
    - ….
  - Schematic design on the injector chain

Parametric design

- General parameters
  - Maintaining parameter lists (according to the design goals)
- Layout designs
  - Eight arcs and long straight sections, and sufficiently long LSSs



SPPC Layout



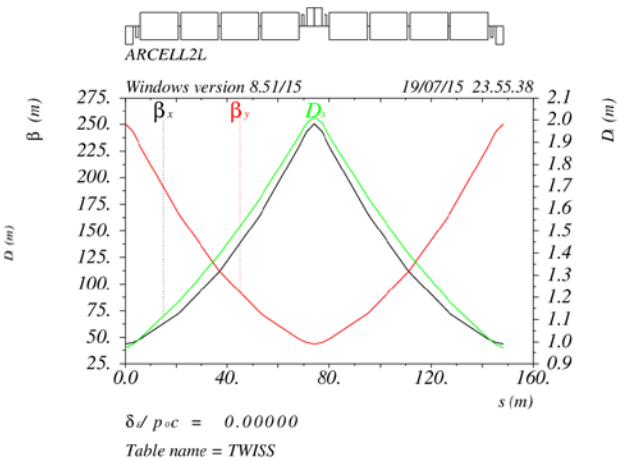
Lattice designs

See Su Feng's Talk

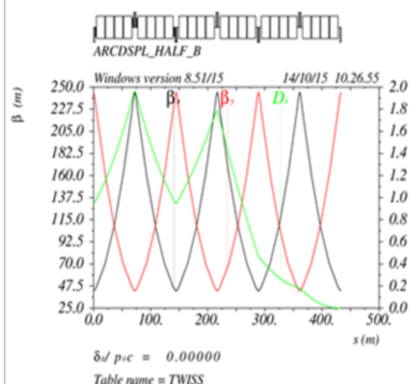
- We have been studying the lattice for different SPPC layouts or design goals
  - Pre-CDR: 54 km, 71 TeV; CDR: 61 km, 71 TeV, 100 km, 100 TeV.
  - Will start on 100 km, 75 TeV, using 12-T magnets (present baseline)
- Design methods and constraints
  - Arc filling factor: >0.78
  - Dispersion suppression methods: half-bend (easy to match, uniform quads), full-bend (higher filling factor), LHC-like (compatible to CEPC, future direction)
  - Lattices for LSSs: IRs, collimation, separation and recombination
  - Different lattice at injection energy and during ramping: larger beta*

Some lattice design results

C=54, 61 km; Similar arc design



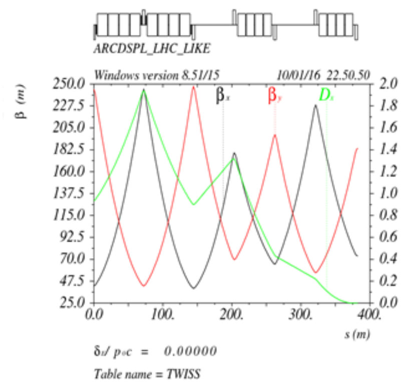
(1) Half Bend



L=423.6(282.4)m

0.78

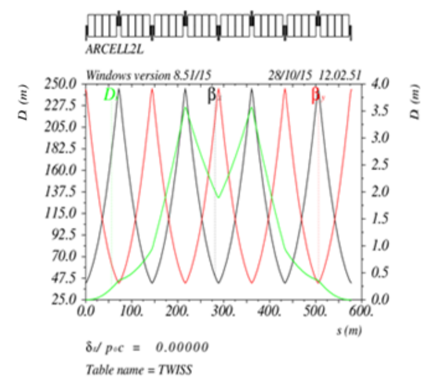
(2) LHC Like



L=382.4m

0.79

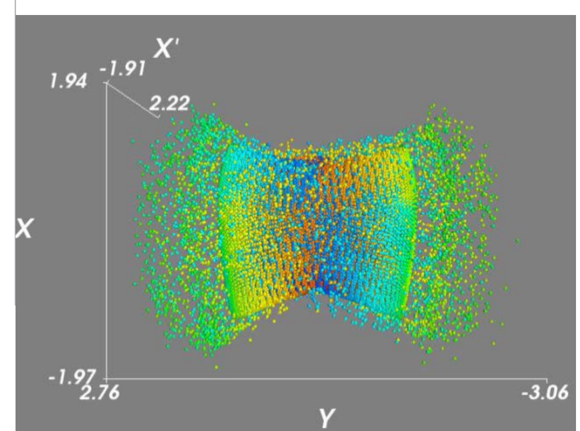
(3) Full Bend



L=564.8m

0.816

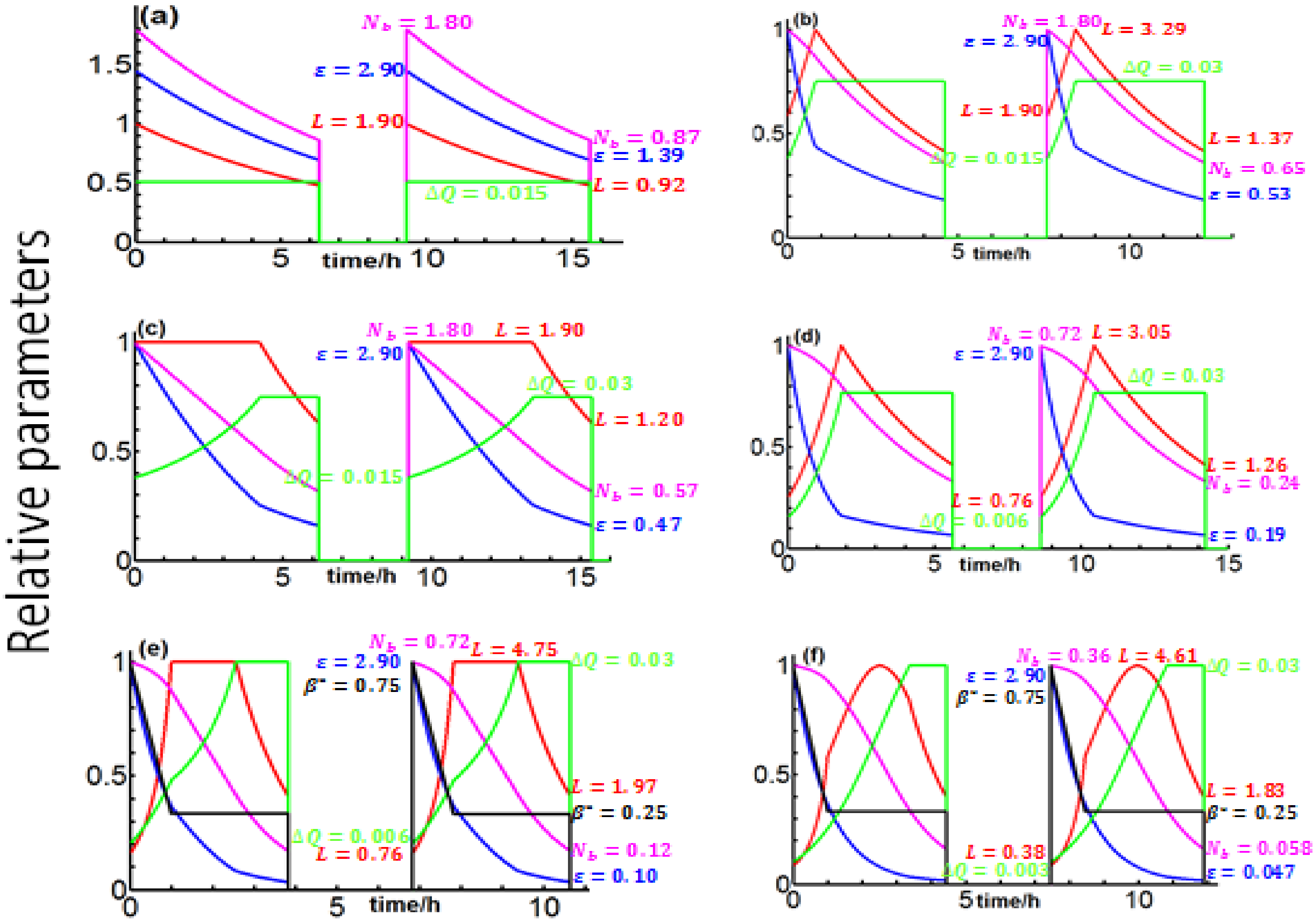
	BDSP1L	BDSP2L	BDSP1R	BDSP2R	B0	
(1)	9.905	9.905	9.905	9.905	19.81	(T)
(2)	18.93	18.93	18.93	18.93	19.81	(T)
(3)	19.81	19.81	19.81	19.81	19.81	(T)



Dynamic aperture studies at collision energy

Luminosity Leveling

- Nominal luminosity defines the one at the collision starting, and it changes during the collision
- Integrated luminosity is more important for physics, so we exploit different schemes to maintain high instantaneous luminosity over collision period or average luminosity.
- Maximum luminosity is limited by the detector pile-up and beam-beam effects
- At SPPC, methods to increase instantaneous luminosity:
  - As emittance shrinks quickly due to synchrotron radiation, we can control the emittance heating to allow modest emittance damping
  - Changing beta* with smaller emittance
  - Allowing beam-beam effect to go up to 0.03
- Other measures
  - Smaller bunch spacing (5 or 10 ns instead of 25 ns) to reduce pile-up
  - Shorter turnaround time to increase average luminosity



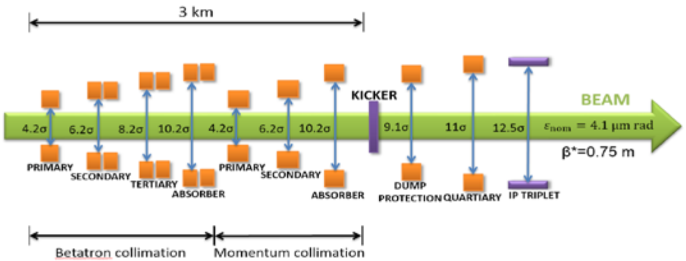
C.M. energy: 100 TeV

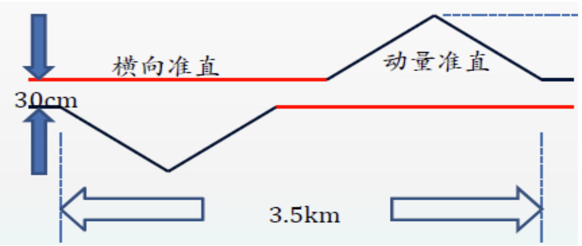
Different luminosity leveling schemes

a) Constant B-B; b) Maximum B-B 0.03; c) Maintaining nominal lumi.; d) 10 ns spacing; e) beta* changing; f) 5 ns spacing

Beam Collimation

- Beam collimation is extremely important and difficult for SPPC (Stored energy: 6.3 GJ @PreCDR)
  - Heavy beam losses: beam-beam interactions, transverse and longitudinal diffusion, residual gas scattering, instabilities and so on (peak loss: MW level)
  - Quench protection of SC magnets
  - Machine protection
  - Hands-on maintenance
  - Cleaning of physics debris
  - Reducing experiment background

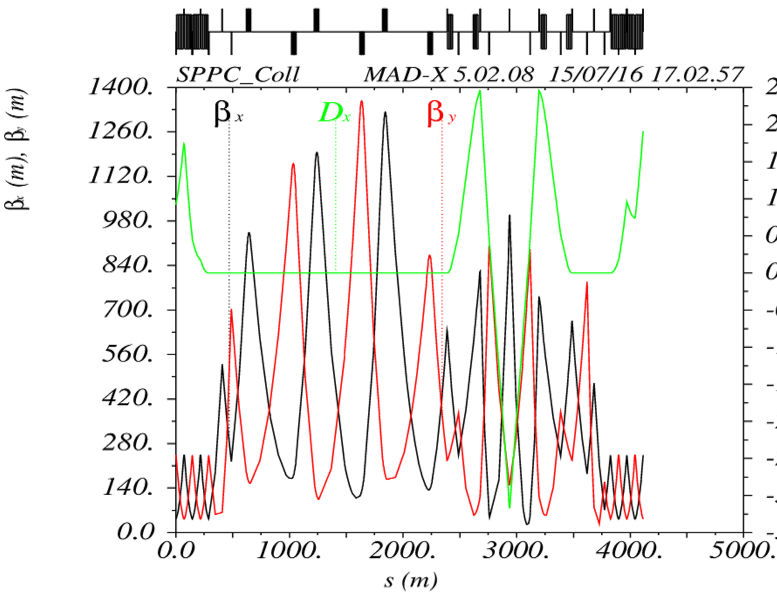




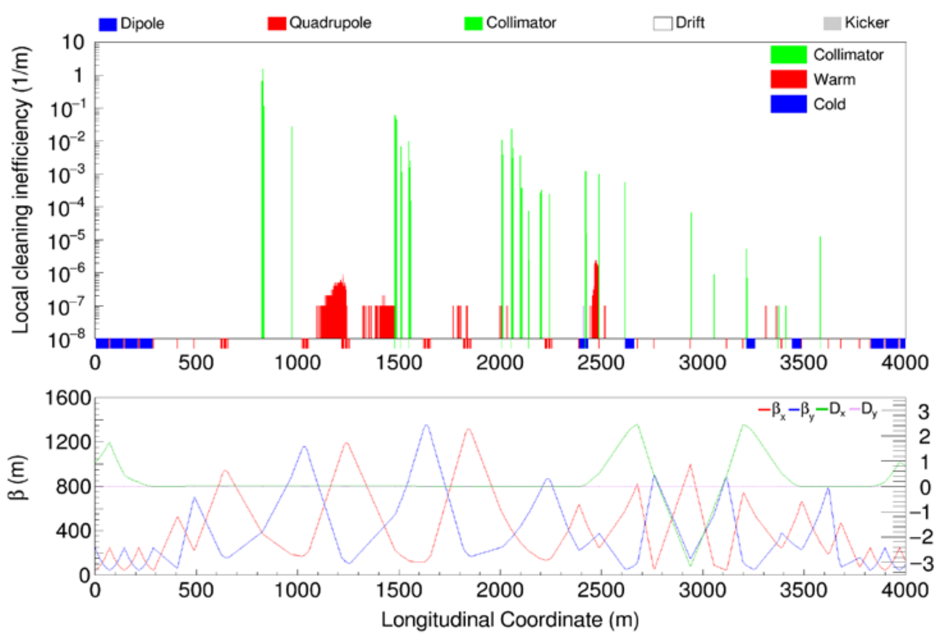
- Key issues: lattice, methods, materials
- New idea: Transverse and longitudinal collimation in the same LSS almost proved by simulations (FCC is also studying the scheme)

Collimation scheme for SPPC

- Single Diffractive Effect: energy loss at transverse collimators, more important at higher beam energy
- Very long straight sections to host both transverse and longitudinal collimators



Lattice for the collimation section

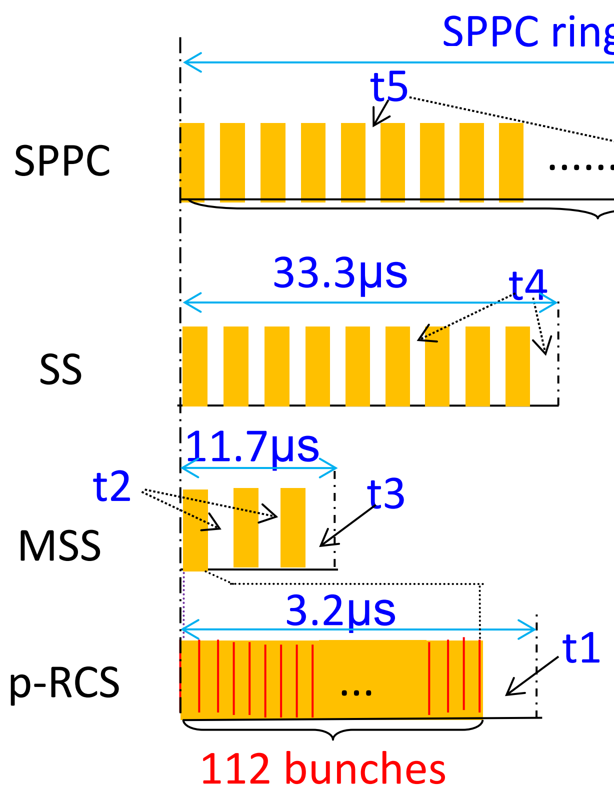


Beam losses by MERLIN Tracking

Bunch filling scheme

- Bunch filling scheme: important for bunching filling factor, related to injector chain, main ring injection

Version for 100km-100TeV



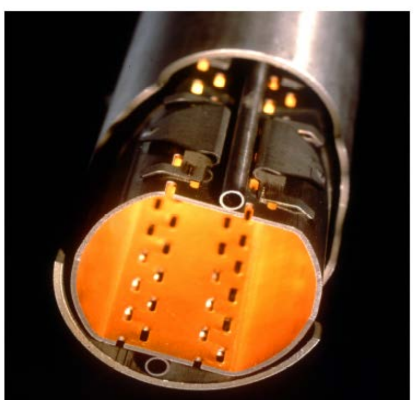
BT: a p-RCS batch with 112 bunches
112*25ns=2.8μs;
t1: p-RCS extraction kicker rise time 400ns;
t2: MSS injection kicker rise time 0.9μs;
t3: MSS extraction kicker rise time 1.5μs;
t4: SS injection/extraction kicker rise time 0.9μs;
t5: SPPC injection kicker rise time 0.88μs;
t6: SPPC beam dump kicker rise time 3.0μs

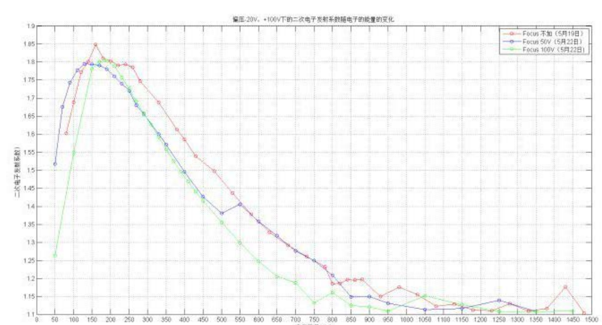
Other accelerator physics studies

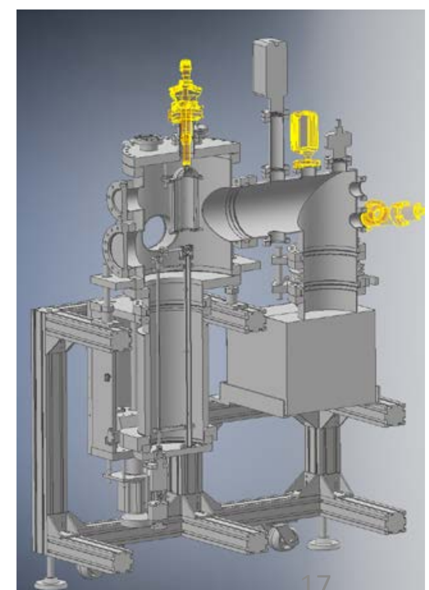
- Instabilities: mainly on electron cloud effects, and also impedance issues related to beam screen.
- Beam-beam effects: phenomenon study, simulations just started; both incoherent and coherent effects; PACMAN effects.
- Injection: multiple injections from SS to SPPC in one SS cycle, to reduce the beam-stored energy less than 5-10 MW
- Extraction: very important for machine protection; very high reliability; beam dilution method at the dump

Impedance and Instabilities

- Analysis on key impedance contributions: beam screens and collimators
- Study on wall impedance for multilayer chamber: analytical and simulations
  - Beam screen: stainless steel (0.6mm) with coating copper (50um), now also HTS
  - Injection protection collimator: hBN (hexagonal boron nitride) coating with Ti (5 um)
  - Others
- Electron cloud study in different sections; characteristics measurements (with a NSFC fund)



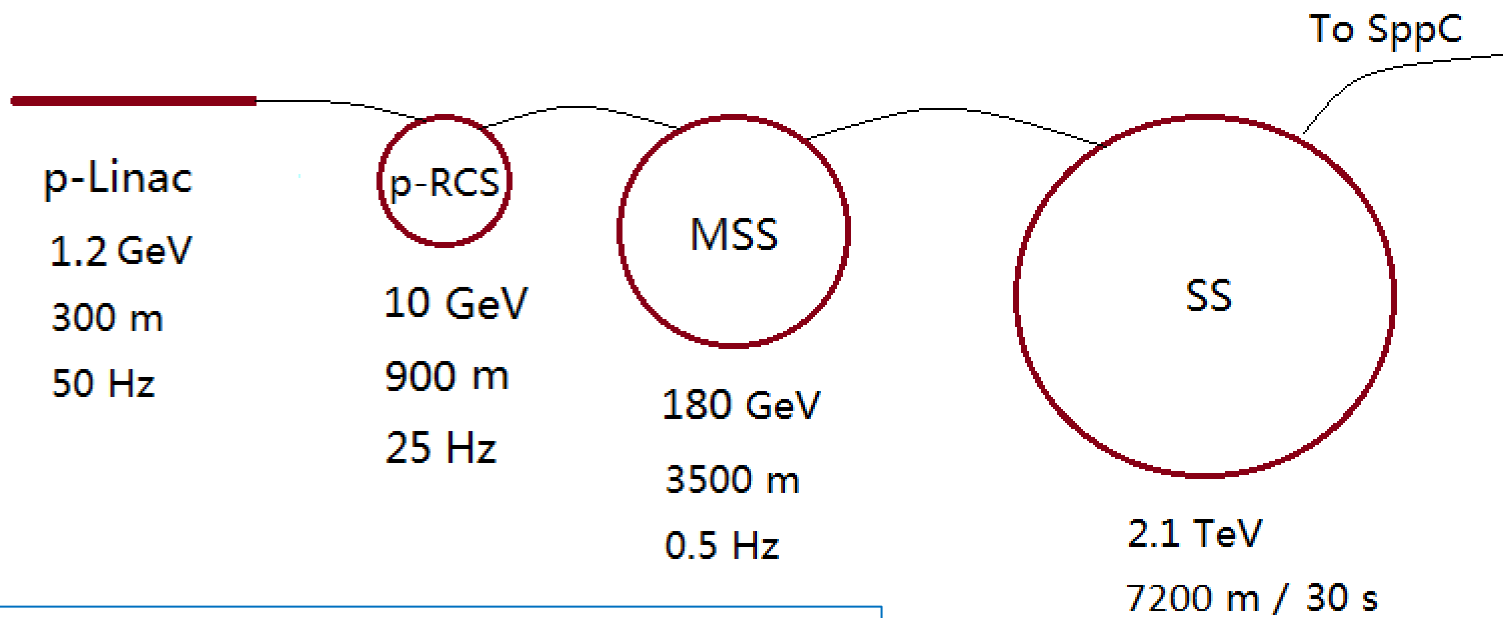




Injector Chain Design Concept

- Injector chain by itself is a very complicated and powerful accelerator system, large enough by a single stage
- Rich physics programs for each stage
- No close reference accelerators (scaled up by large factors)
  - Totally new, different from LHC or Tevatron (building-up by steps)
- Design work on each accelerator started: scheme, lattice and even more details (not only feeding the collider but also independent physics program)
- Key technical challenges should be identified, so needed R&D program can be pursued.

Injector chain
(for proton beam, 2.1 TeV)



p-Linac: proton superconducting linac

p-RCS: proton rapid cycling synchrotron

MSS: Medium-Stage Synchrotron

SS: Super Synchrotron

Ion beams have dedicated linac (i-Linac) and RCS (i-RCS)

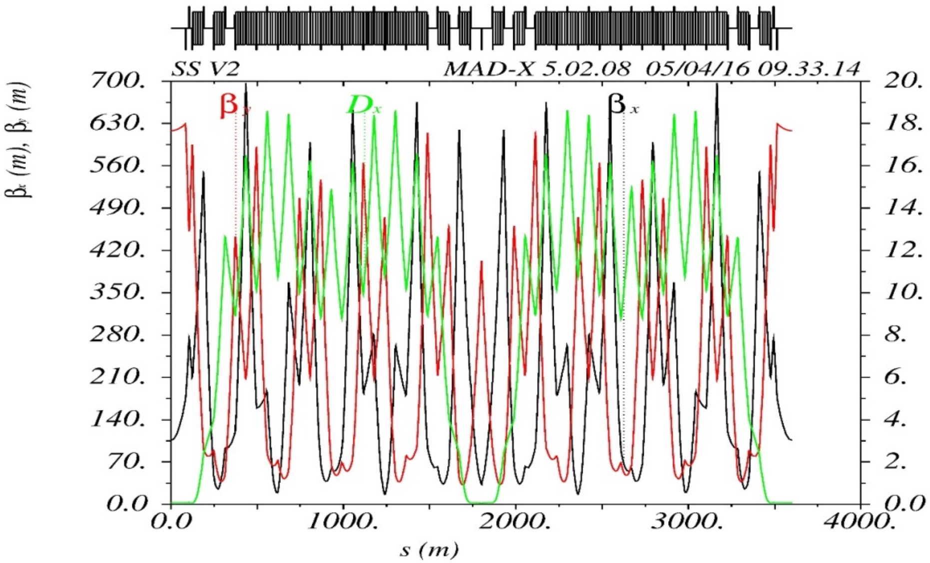
Major parameters for the injector chain

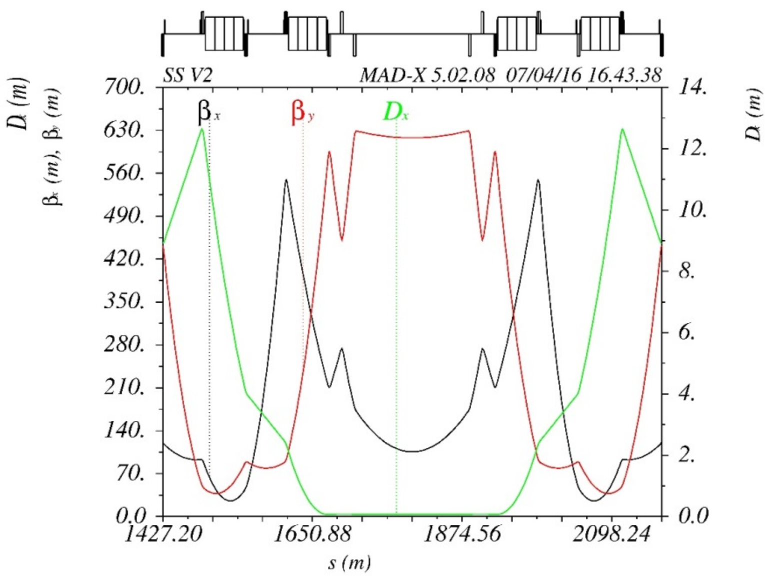
	Value	Unit		Value	Unit
p-Linac			MSS		
Energy	1.2	GeV	Energy	180	GeV
Average current	1.4	mA	Average current	20	uA
Length	~300	m	Circumference	3500	m
RF frequency	325/650	MHz	RF frequency	40	MHz
Repetition rate	50	Hz	Repetition rate	0.5	Hz
Beam power	1.63	MW	Beam power	3.67	MW
p-RCS			SS		
Energy	10	GeV	Energy	2.1	TeV
Average current	0.19	mA	Accum. protons	2.55E14	
Circumference	900	m	Circumference	7200	m
RF frequency	36-40	MHz	RF frequency	200	MHz
Repetition rate	25	Hz	Repetition period	30	s
Beam power	3.4	MW	Protons per bunch	2.0E11	
			Dipole field	8.3	T

Will use high-Q ferrite-loaded RF cavities for RCS and MSS

SS – Super Synchrotron

- Layout and preliminary lattice design: race-type lattice
- Dynamic aperture calculations
- Extraction considerations: multiple extractions, 10 Hz
- Fast ramping issue: 30-s cycling time, 8.3-T SC magnet, very challenging





STUDIES ON KEY TECHNICAL ISSUES

- Although there are many technical challenges in building SPPC and the injector chain, most of them can be waited to be solved a few years before construction. Actually we have identified two key technologies for long-term and early R&D:
  - High-field SC magnets: extremely challenging, needing very heavy R&D efforts with global collaboration
  - Beam screen: potential show-stopper, very complicated (vacuum, beam instability, mechanical support, cryogenics, magnet aperture), needing to develop special structure and material coating
- Recently adjusted SPPC goals
  - Reducing magnetic field but requiring all-HTS technology
  - 12-T/75-TeV: four times lower synchrotron radiation load per meter

R&D plan of the 20-T magnet technology

Old planning, the new one is under preparation

- **2015-2020**

Development of a 12-T operational field Nb_3Sn twin-aperture dipole; Fabrication and test of 2~3 T HTS (Bi-2212 or YBCO) coils in a 12-T background field, and basic study on tape superconductors for accelerator magnets (field quality, fabrication method, quench protection).

Assume with enough funding!

- **2020-2025**

Development of 15-T Nb_3Sn twin-aperture dipole and quadrupole with 10^{-4} field uniformity; Fabrication and test of 4~5 T HTS (Bi-2212 or YBCO) coils in a 15-T background field.

- **2025-2030**

Nb_3Sn coils + HTS coils (*or only one of them*) to realize the 20-T dipole and quadrupole with 10^{-4} field uniformity; Development of the prototype SPPC dipole/quadrupole and infrastructure build-up.

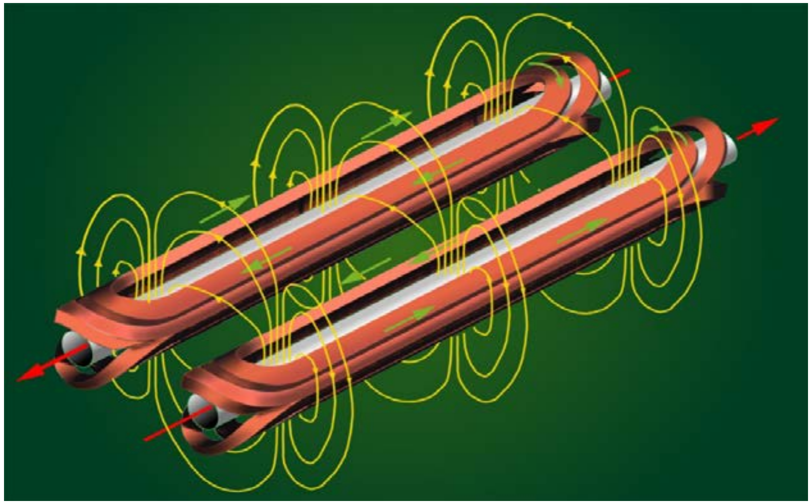
R&D plan of the 20-T magnet technology

(2015-2020)

***Magnetic & mechanical design study:** coil configuration, field quality, stress management, …*

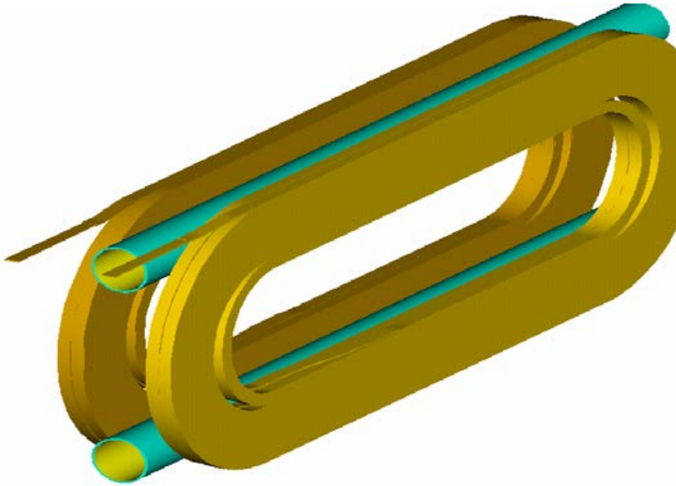
Cos-**th**eta dipole

High efficiency, complicated ends with hard-way bending



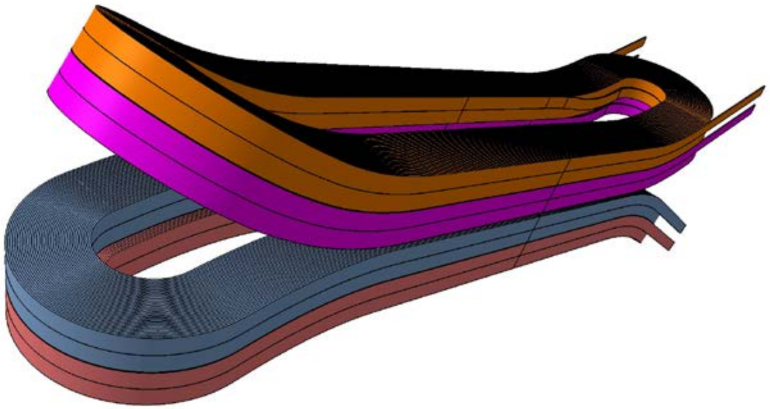
Common coil dipole

Simplest structure with large bending radius, low efficiency



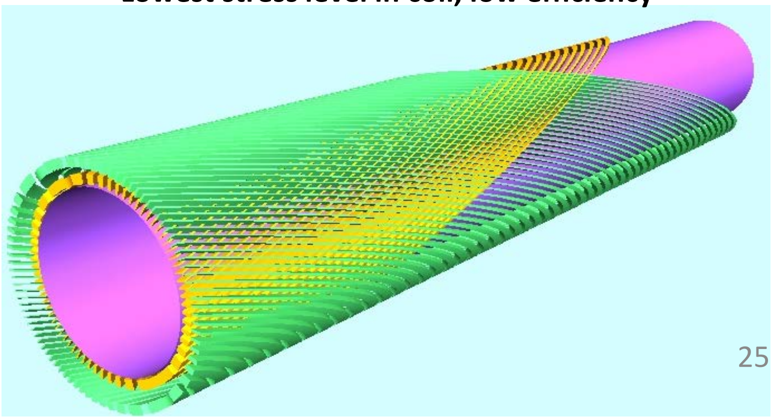
Block type dipole

Simpler structure with hard-way bending, low efficiency



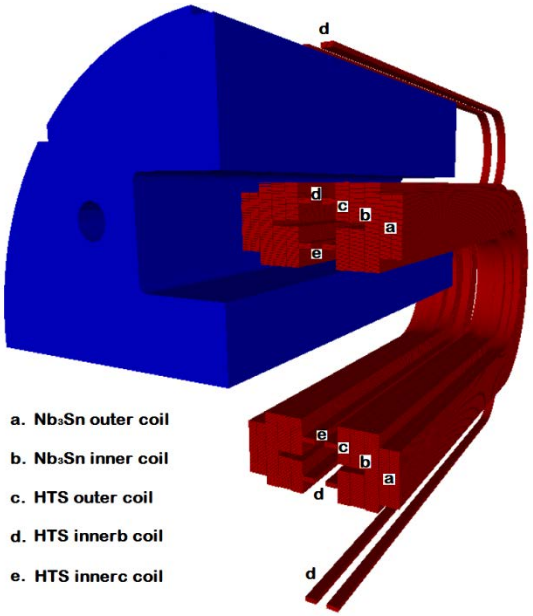
Canted cos-theta dipole

Lowest stress level in coil, low efficiency



Magnet design, prototyping and infrastructure

- Work is focused on:
  - Design Study of the SPPC Dipole Magnet
  - R&D Steps for the SPPC Dipole Magnet
  - Development of Nb3Sn Rutherford Cable
  - R&D of High Field ReBCO Tape by SSTC
  - R&D of Bi-2212 Superconductor by NIN
  - Preparation for the Model Magnet R&D
- Very slow building-up of infrastructure
- Domestic and international collaborations

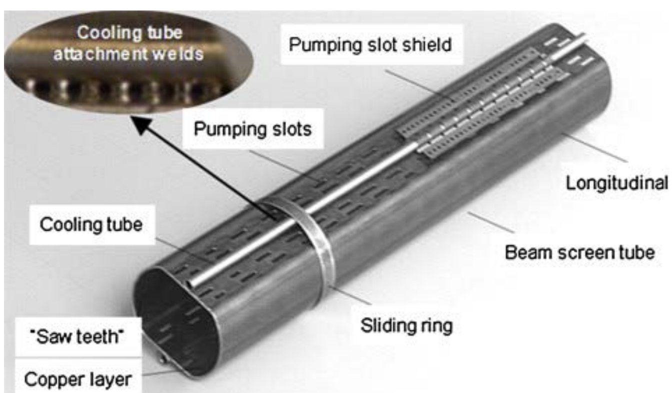


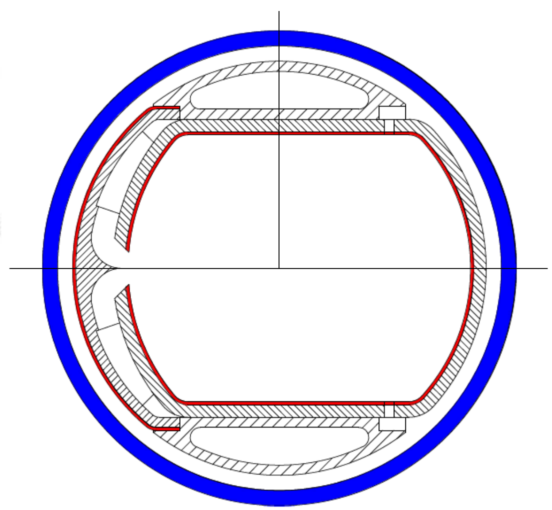
Promoting collaboration on HTS technology

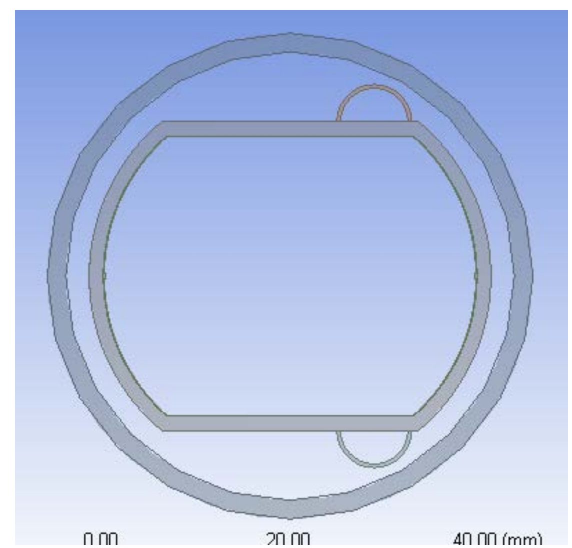
- SPPC high-field superconducting magnets: HTS has a great potential for future superconducting magnets, especially with expectation of a large reduction in cost.
- China has a good ground in high-temperature superconductors, both in basic research and applications. We use SPPC as a driving force to unify domestic institutions to develop HTS, especially iron-based HTS. A collaboration has been established.

Beam screen and vacuum

- Synchrotron radiation poses critical challenges to the cryogenic vacuum in next-generation pp colliders. Beam screen (shielding the light) is seen a potential stopper of the colliders.
- Screen structure under study: ante-chamber for absorbing photos, HTS coating to reduce impedance, high-temperature 45-65 K to reduce cryogenic load







- Beam instrumentation and controls
  - Very fast and reliable beam instrumentation and controls for both machine protection and sophisticated beam manipulations (emittance blow-up, luminosity leveling etc.)
- Machine protection
  - It is tough to deal with 6.3 GJ energy at max in beam, and also huge energy stored in magnets. A workable and reliable machined protection system is critical for operating the machines
- RF systems
  - It is interesting to develop high-Q ferrite-loaded RF cavities for two fast ramping synchrotrons: p-RCS and MSS
- Cryogenics
  - Efficiency is important for super-large scale cryogenic system.

Summary

- We have been making progress on SPPC study steadily, covering the scope and many challenging topics.
- Study with newly defined SPPC goals will start soon.
- Strong domestic collaboration on HTS technology will support the SPPC magnet development.
- SPPC chapter in the CDR report will be ready by end 2017.
- Much welcome international experts join SPPC study.

THANKS FOR ATTENTION!