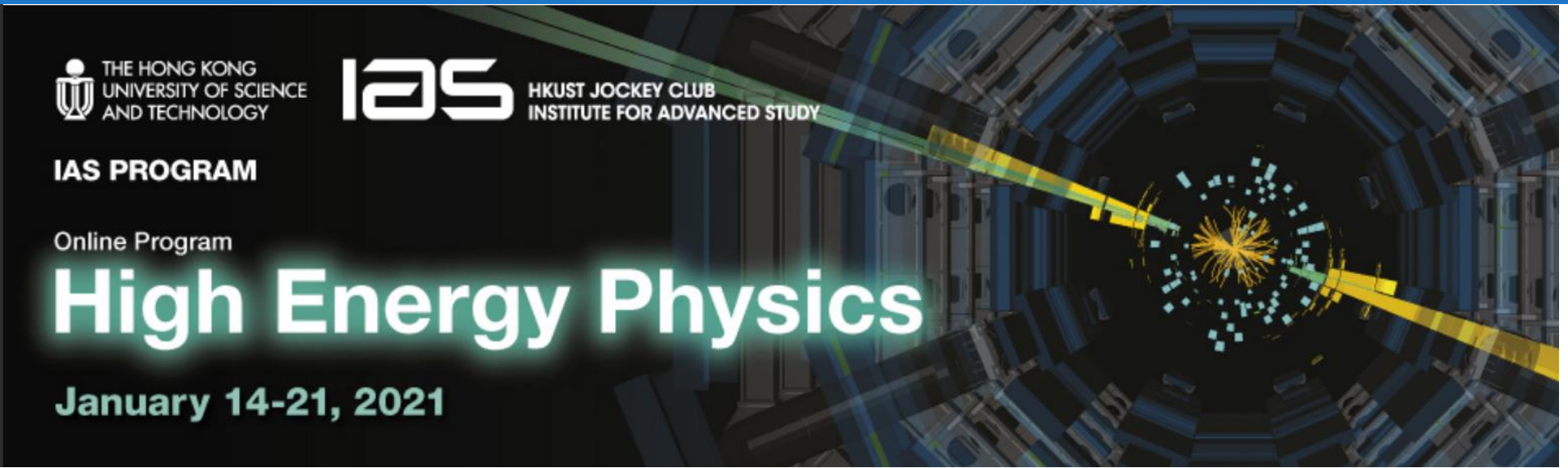
中国科学院高能物理研究所
Institute of High Energy Physics
Chinese Academy of Sciences

环形正负电子对撞机
Circular Electron Positron Collider

CEPC Injector

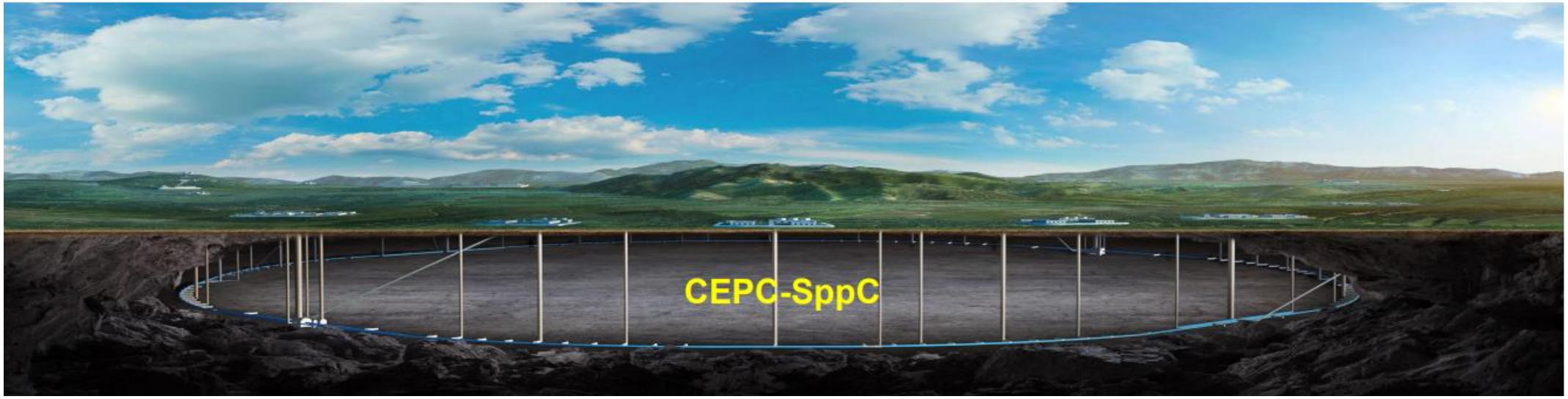


C. Meng,

on behalf of CEPC AP group, IHEP

Outline

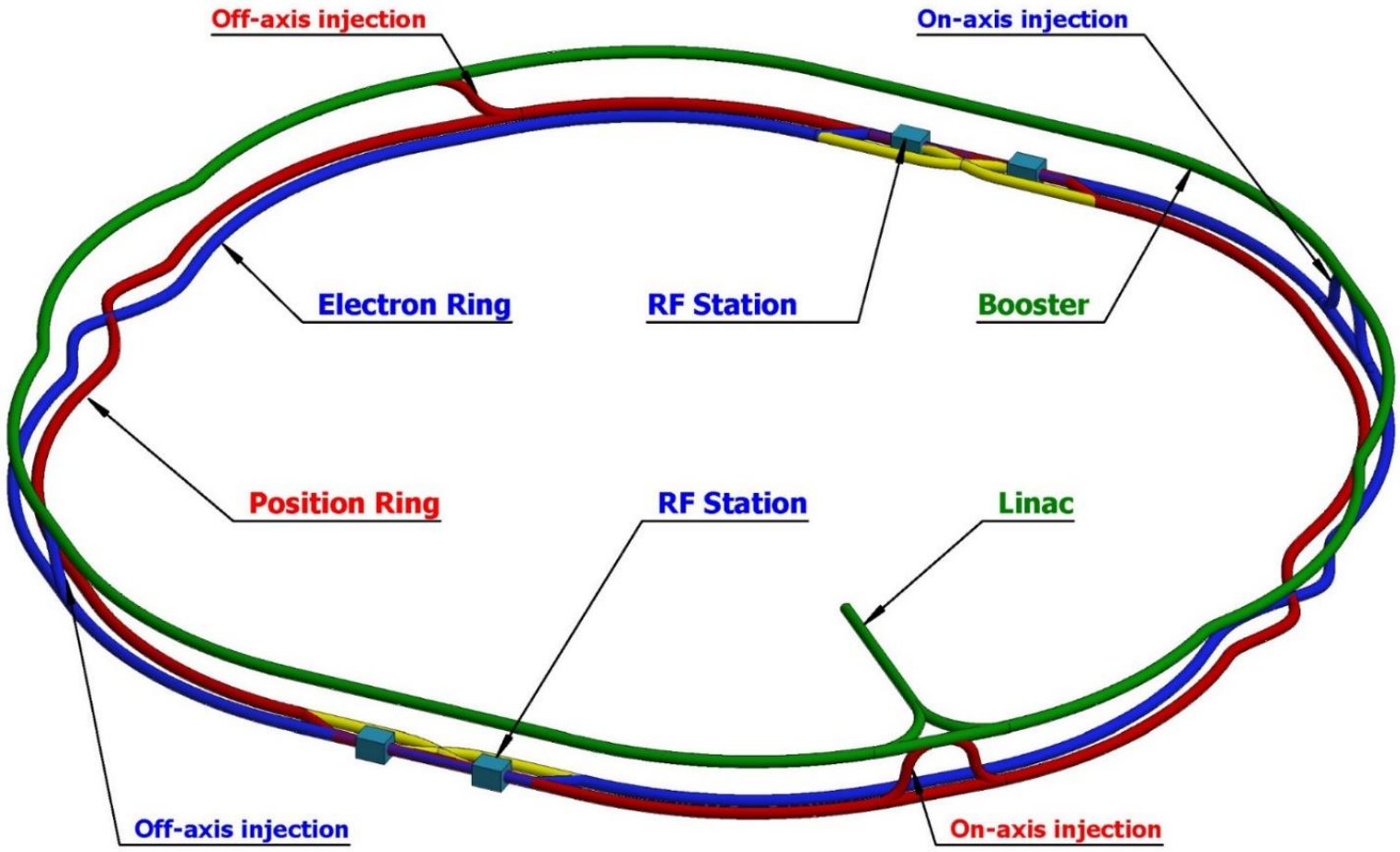
- **Introduction**
- Progress on CEPC Linac design
- Summary



Introduction

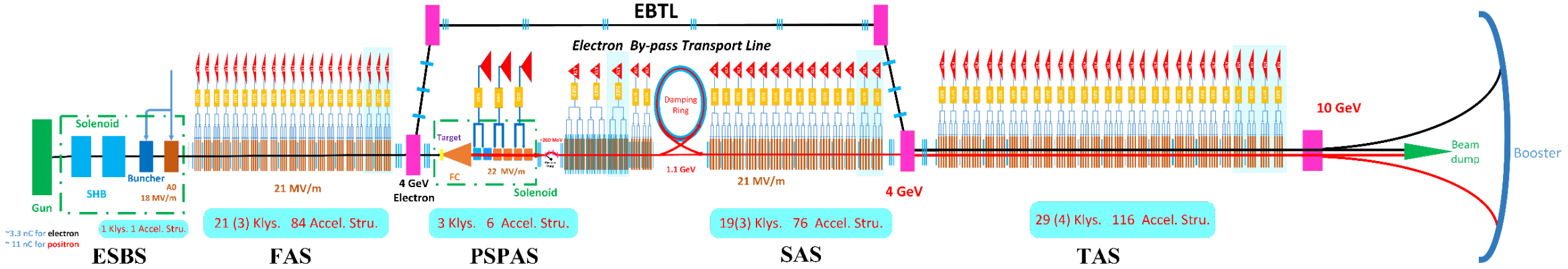
CEPC layout

- CEPC as a Higgs (W, Z) Factory
  - 100 km
- CEPC layout
  - 10 GeV injector - Linac
  - 10-120GeV Booster
  - 120 GeV Collider
  - Transport lines

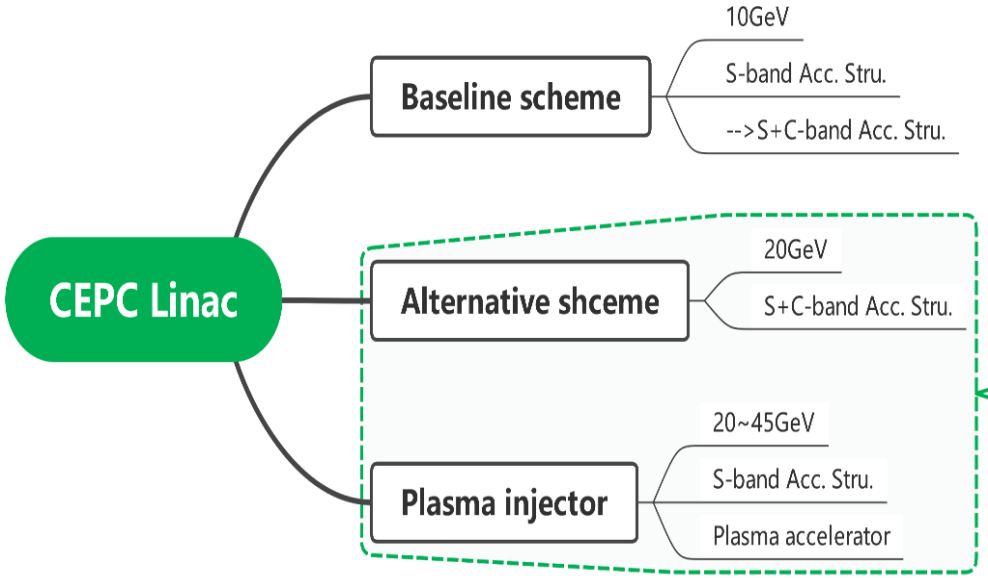


- CEPC Linac
  - Baseline scheme
    - ✓ 10 GeV (S-band)
    - ✓ Conventional positron source
      - ☐ 4GeV electron beam @ target
      - ☐ Fixed target
    - ✓ Damping ring for positron beam

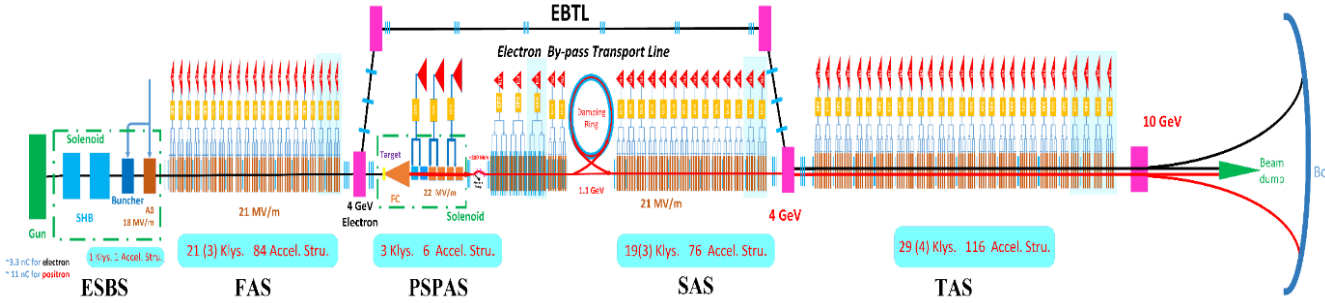
Parameter	Symbol	Unit	Baseline
e^-/e^+ beam energy	E_{e-}/E_{e+}	GeV	10
Repetition rate	f_{rep}	Hz	100
e^-/e^+ bunch population	*Ne-/Ne+*		9.4×10^9
		nC	1.5 (3)
Energy spread (e^-/e^+)	σ_E		2×10^{-3}
Emittance (e^-/e^+) Req.	ε_r	nm	40

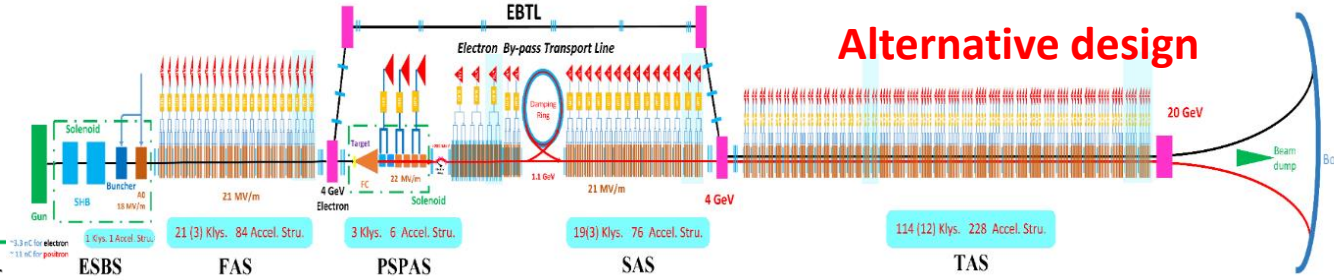


CEPC Linac



Low magnetic the Booster dipole @ low energy

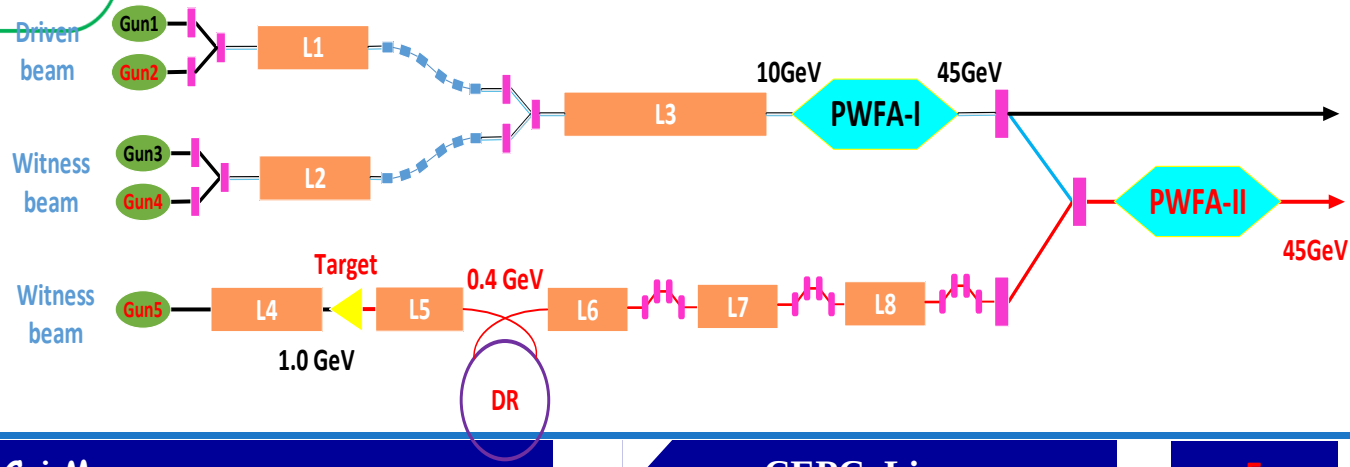




Alternative design

S-band Accelerating structure

C-band Accelerating structure



Introduction forward

- With the continuous improvement of the performance and capabilities of the CEPC, the requirements for the Linac also is being updated
  - Design for larger parameter range and more potential
  - 10nm-emittance for "High luminosity scheme at Higgs energy"
    - ✓ 120nm→40nm→**10nm**
  - two-bunch-per-pulse or 200-Hz-repetition rate for "High luminosity scheme at Z energy" ?
- Update design for the baseline scheme and alternative scheme

Parameter	Symbol	Unit	Baseline
e^-/e^+ beam energy	E_{e-}/E_{e+}	GeV	10
Repetition rate	f_{rep}	Hz	100
e^-/e^+ bunch population	*Ne-/Ne+*		9.4×10^9
		nC	1.5 (**3**)
Energy spread (e^-/e^+)	σ_E		2×10^{-3}
Emittance (e^-/e^+) Req.	ε_r	nm	40→**10**

Outline

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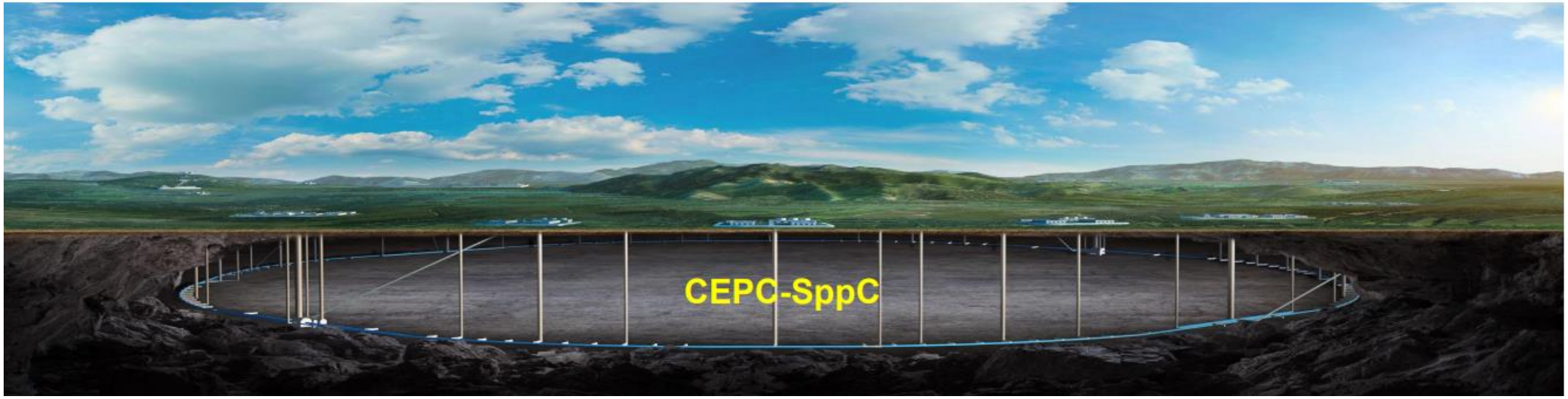
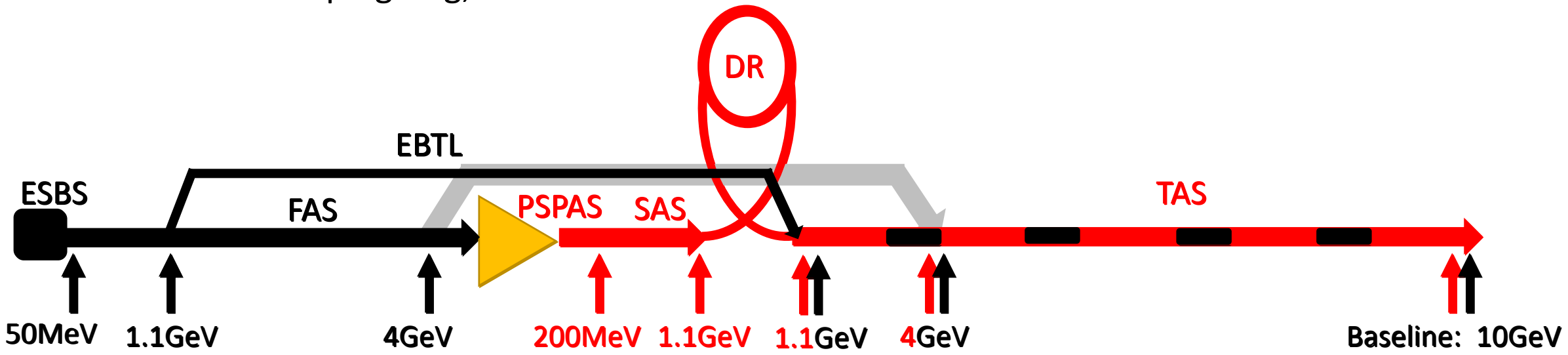
- **Progress on CEPC Linac design**
- Summary



Progress on Linac

Baseline scheme

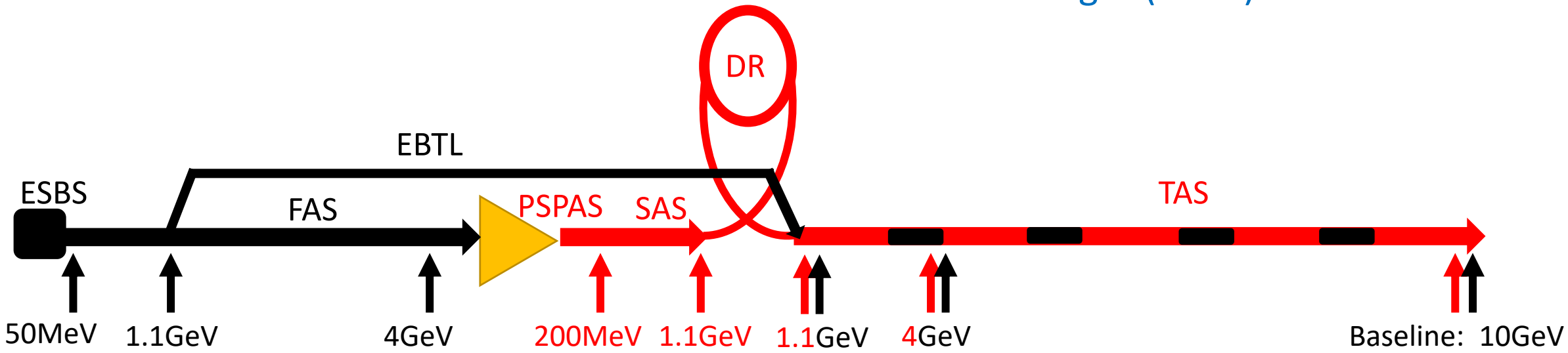
- The energy of electron bypass transport line (EBTL) is from 4GeV to 1.1 GeV
  - Reduce the survey design difficulty of the positron source
  - Better compatibility between baseline scheme and alternative scheme
    - ✓In this case the starting energy of the C-band accelerating structure can be 1.1 GeV just after damping ring;



Progress on Linac

Baseline scheme

- The deflection direction of the EBTL is from horizontal to vertical, the distance between EBTL and main linac is from 2 m (H) to 1.2 m (V)
  - Easier layout design to avoid the interference with energy analyzing station, transport lines between the Linac and damping ring, waveguide and positron source
  - Reduce the tunnel width and no need to increase the height (3.5m)

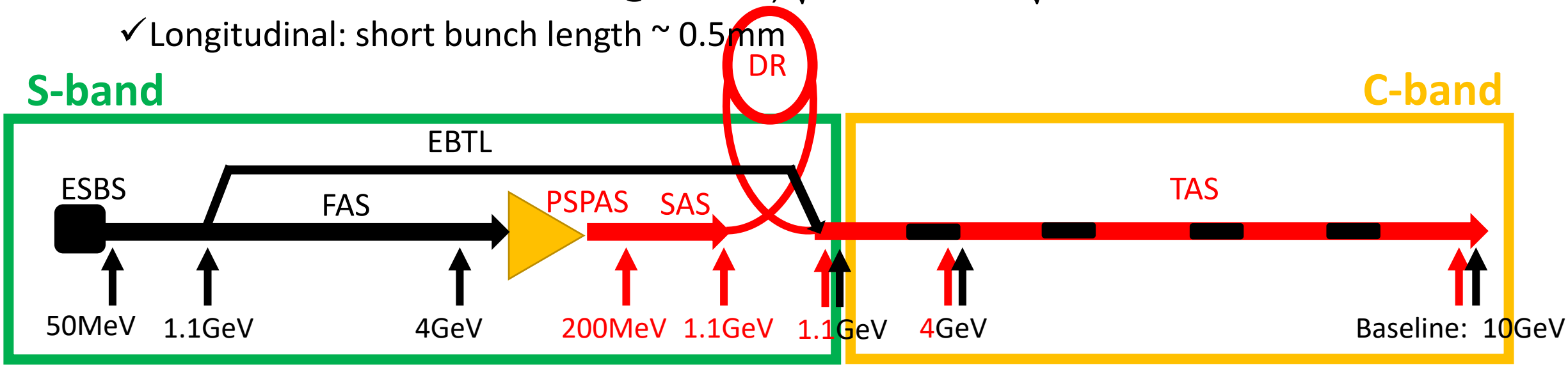


Progress on Linac

Baseline scheme

- Emittance → 10nm @ 10GeV
  - Electron beam
    - ✓Norm. RMS. emittance is 100 mm-mrad → 5.1 nm
  - Positron beam
    - ✓Lower emittance Damping ring is under design
  - C-band accelerating structure from 1.1GeV
    - ✓Transverse: emittance is 91 nm@1.1GeV , $\sqrt{\varepsilon} = 3 \times 10^{-4}\sqrt{m}$
    - ✓Longitudinal: short bunch length ~ 0.5mm

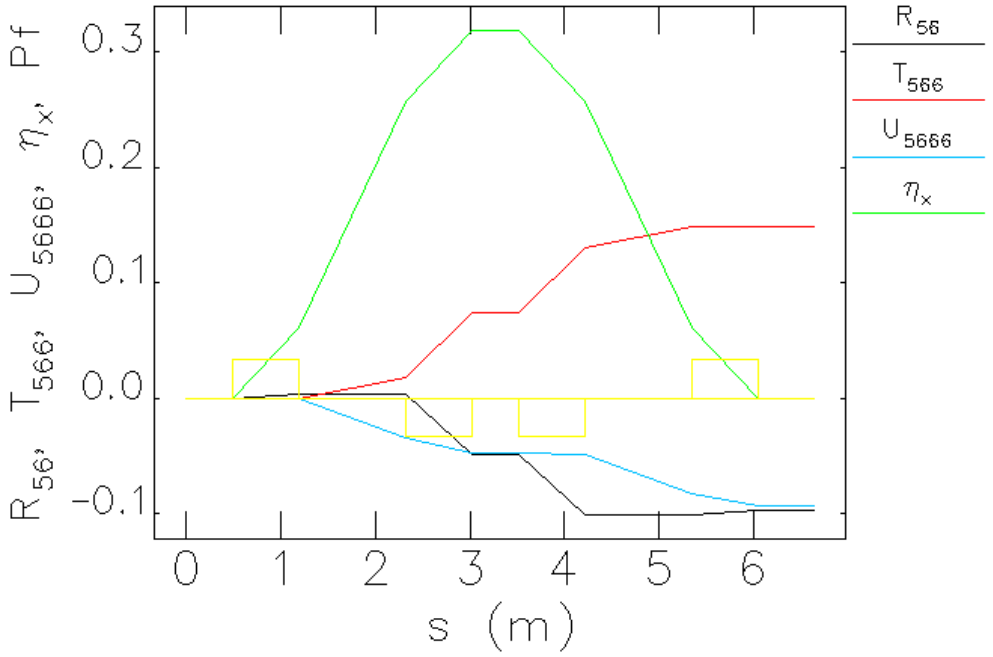
Parameter	Unit	S-band	C-band
Frequency	MHz	2860	5720
Length	m	3.1	1.8
Cavity mode		2π/3	3π/4
Aperture diameter	mm	20~24	11.8~16
Gradient	MV/m	21	**45**

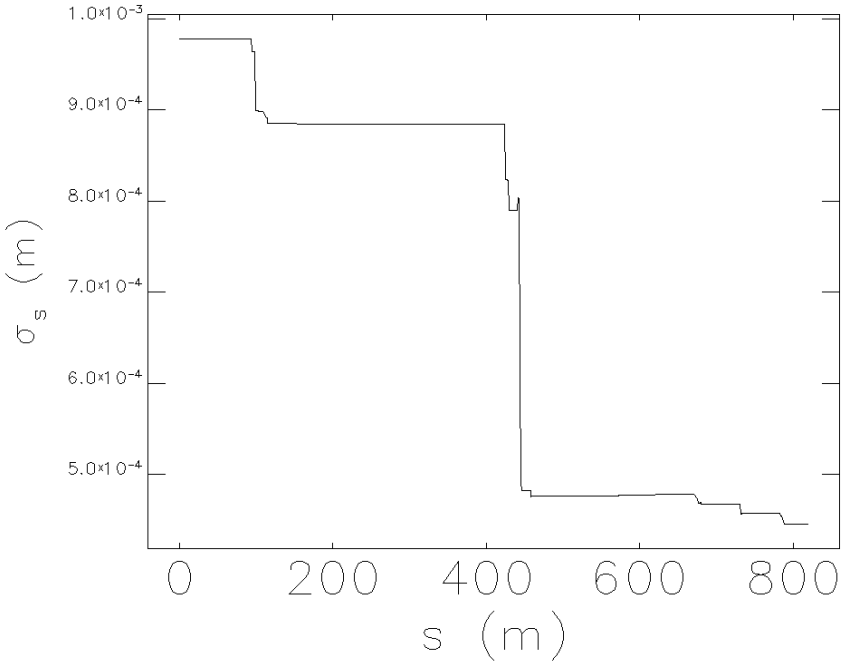


Progress on Linac

Chicane

- A chicane at the beginning of TAS was introduced to compress bunch length for C-band accelerating structure.
- C-type Chicane as bunch length compressor
  - Angle: 175mrad
  - R56=-0.1m

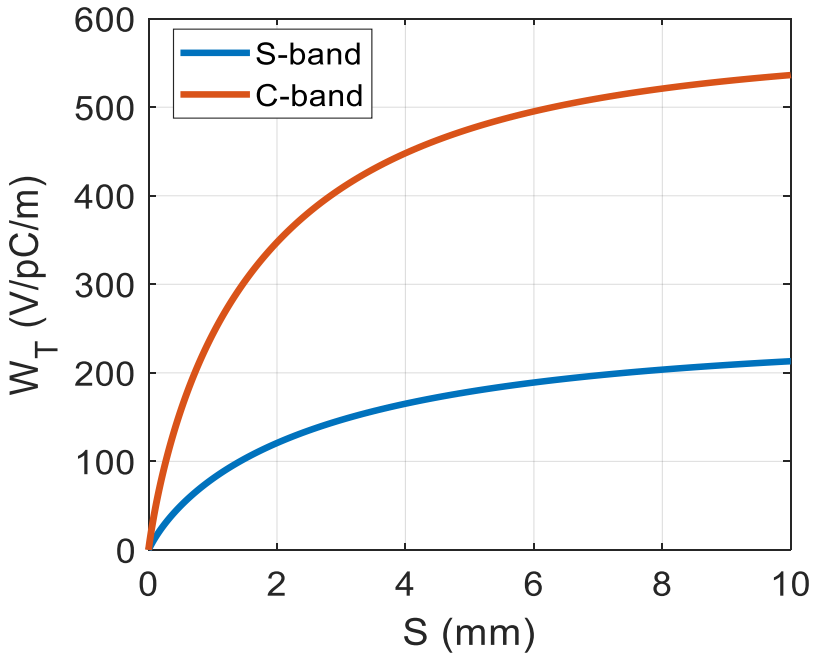


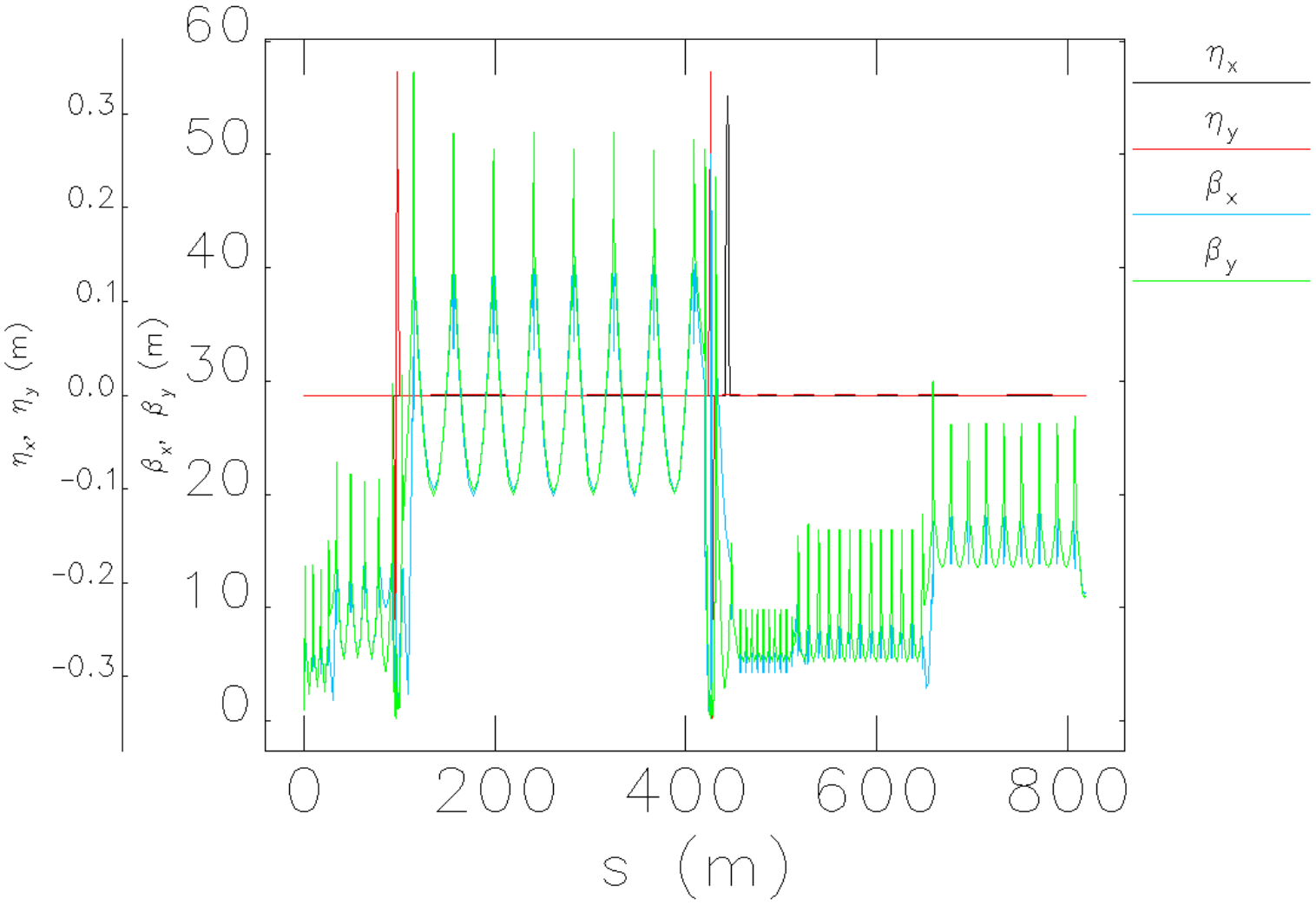


Progress on Linac

Baseline

- Optics function
- Challenge
  - Wakefield effect
    - ✓ Emittance growth
  - Beam orbit correction

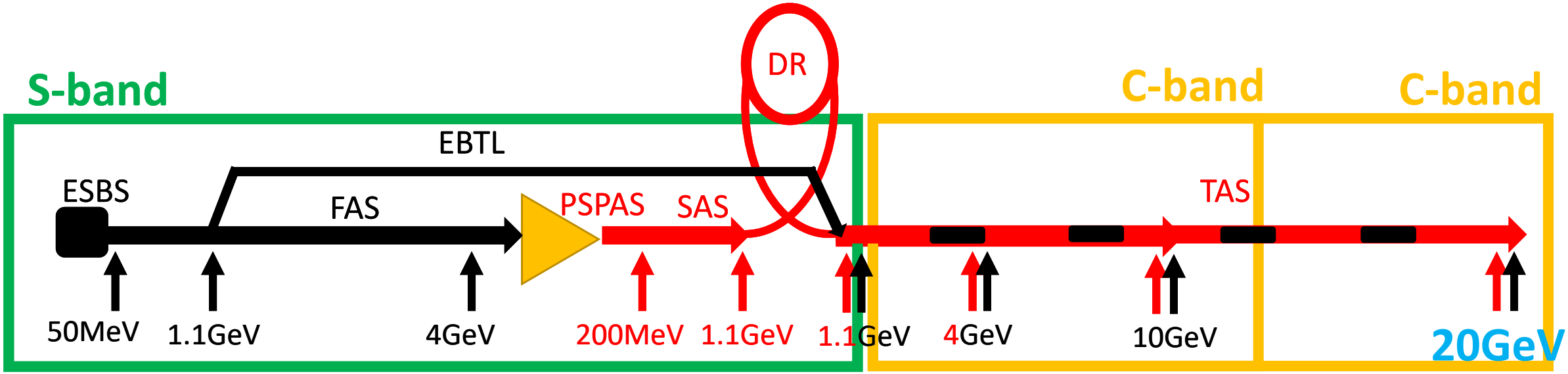




Progress on Linac

Alternative scheme

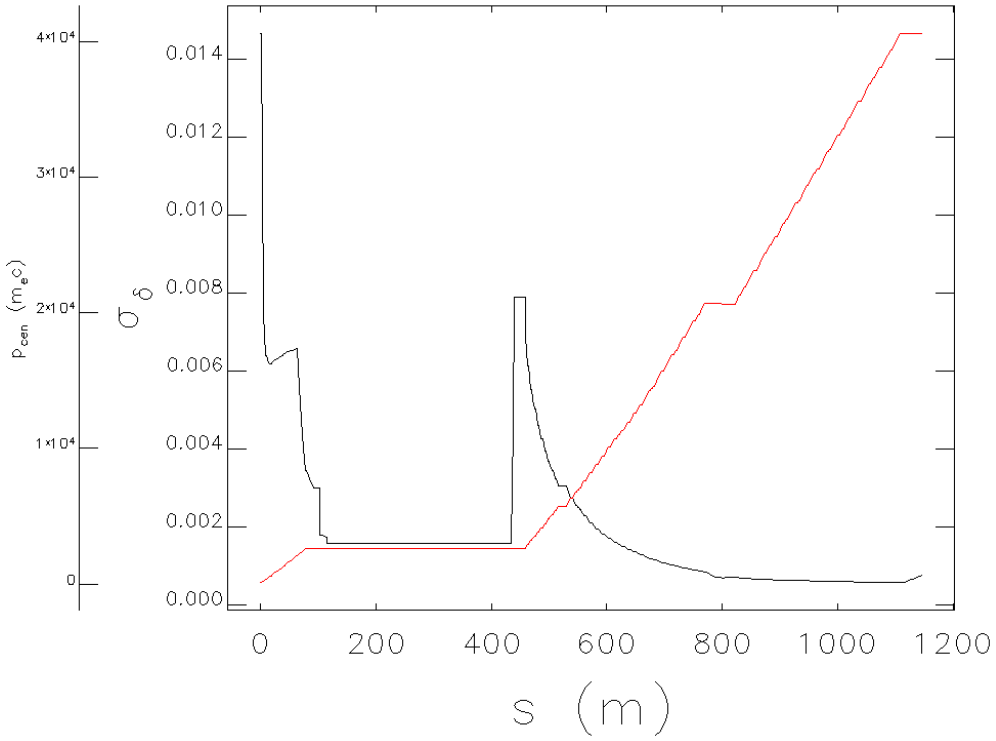
- The alternative scheme
  - energy → 20GeV
  - More C-band accelerating structures after the baseline scheme

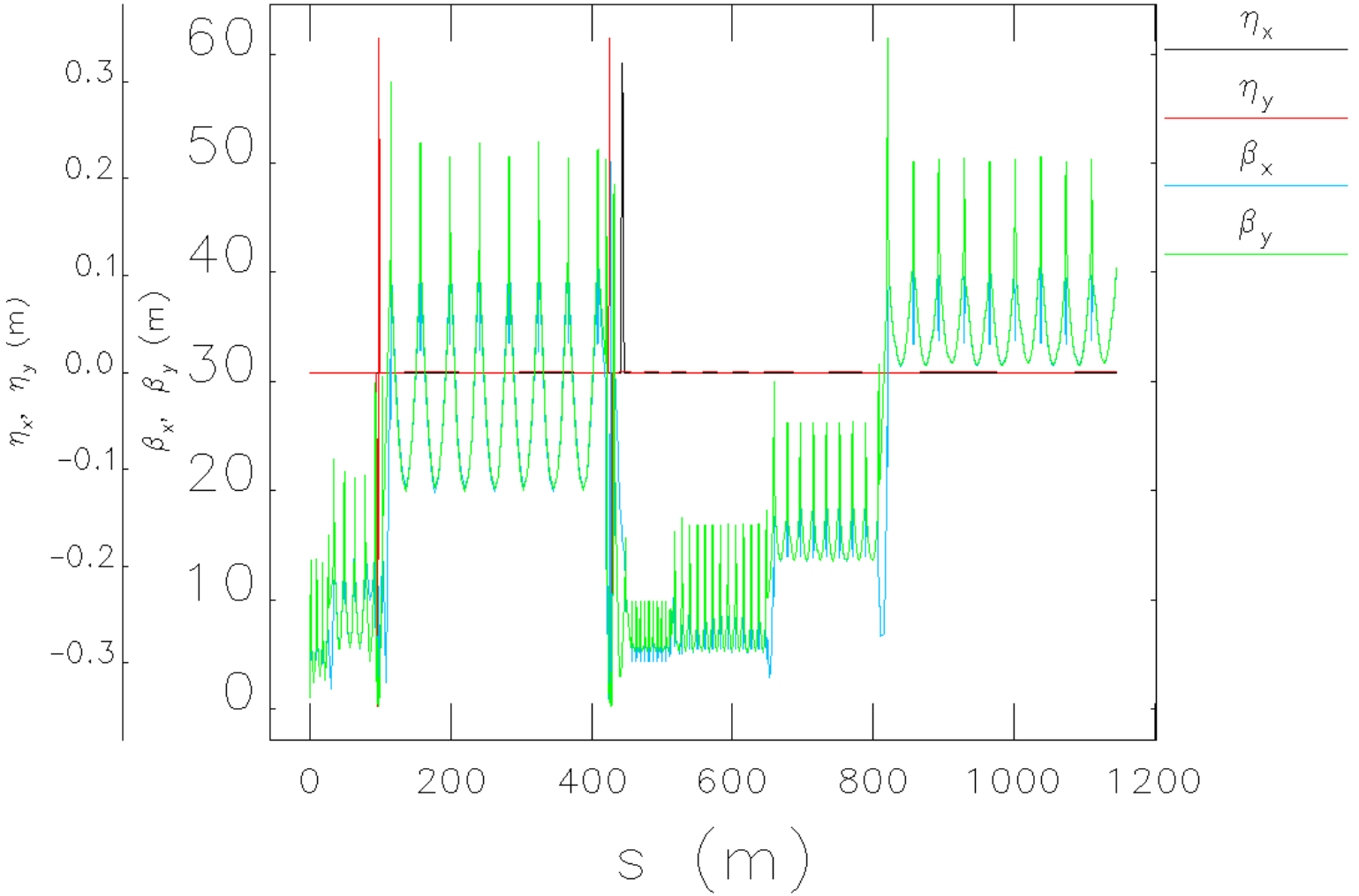


Progress on Linac

Alternative scheme

- The alternative scheme
  - Error study should be checked
    - ✓ Emittance growth

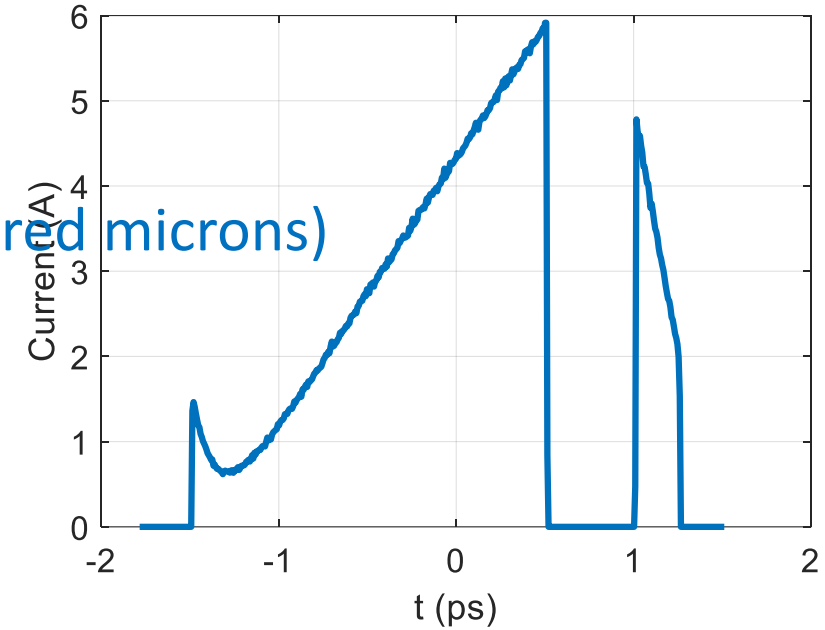


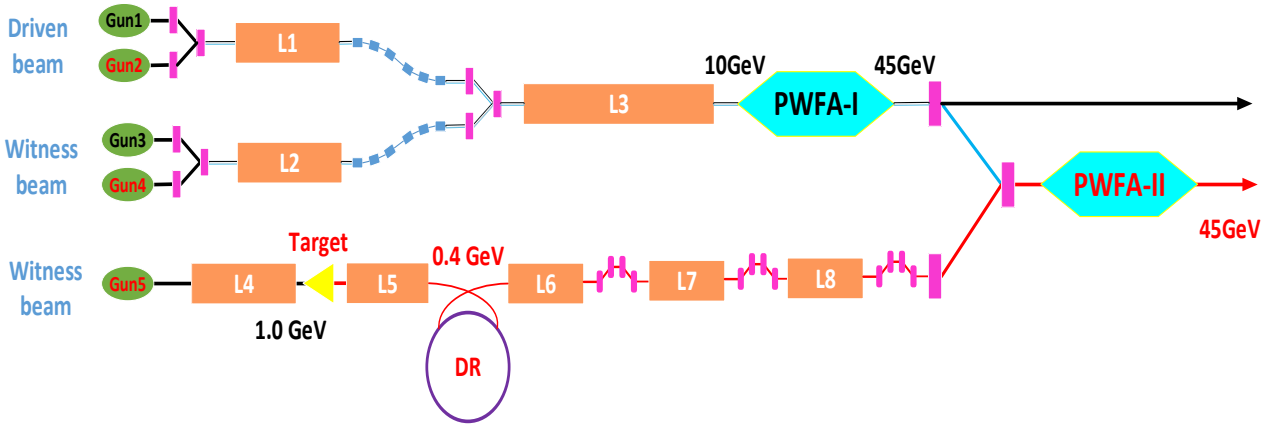


Progress on Linac

PWFA scheme

- Beam driven plasma wakefield acceleration
- Challenging design
  - high bunch charge (5nC~20nC)+ short bunch length(hundred microns)
  - Longitudinal shape modulation and compressor
  - FFS
    - ✓ $\beta_* = 156.0\,mm\ \ (V1.0)$
    - ✓ $\beta_* = \ \ 14.6\,mm\ \ (V2.0)$





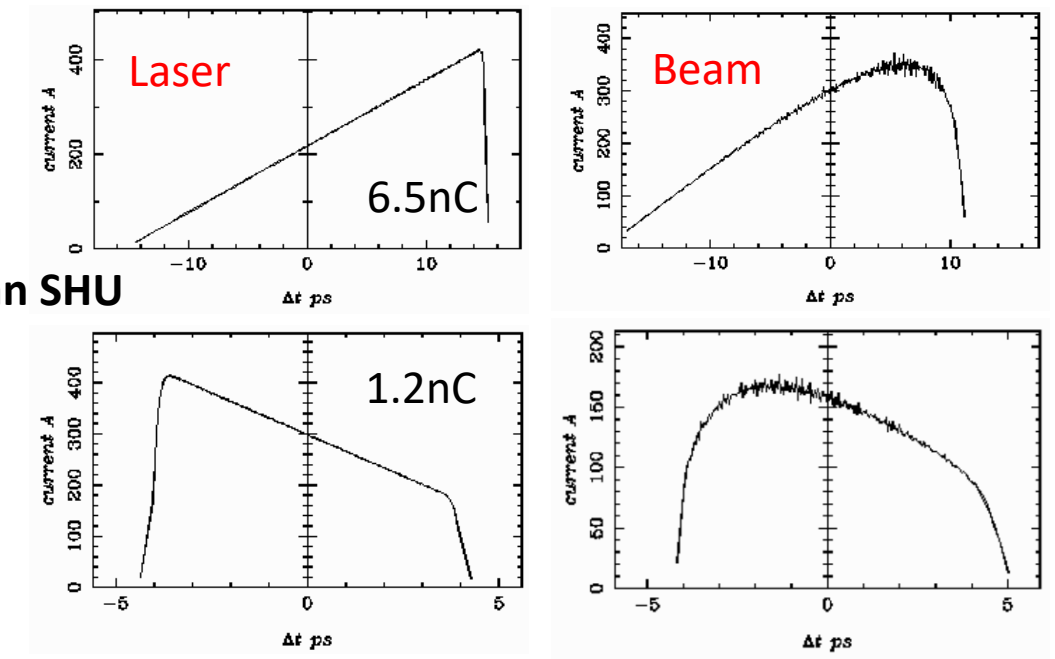
Electron acceleration	Unit	Driven bunch		Trailer bunch	
		V1.0	V2.0	V1.0	V2.0
Energy	GeV	10	10	10	10
Bunch charge	nC	5.8	5.8	1.0	0.84
Bunch length	ps	2		0.267	0.257
Bunch space	ps	0.497			
Energy spread		-	≤0.2%		≤0.2%
Norm. rms emittance	mm·mrad	50	20	100	100
Beam size	μm	20	3.87	20	8.65

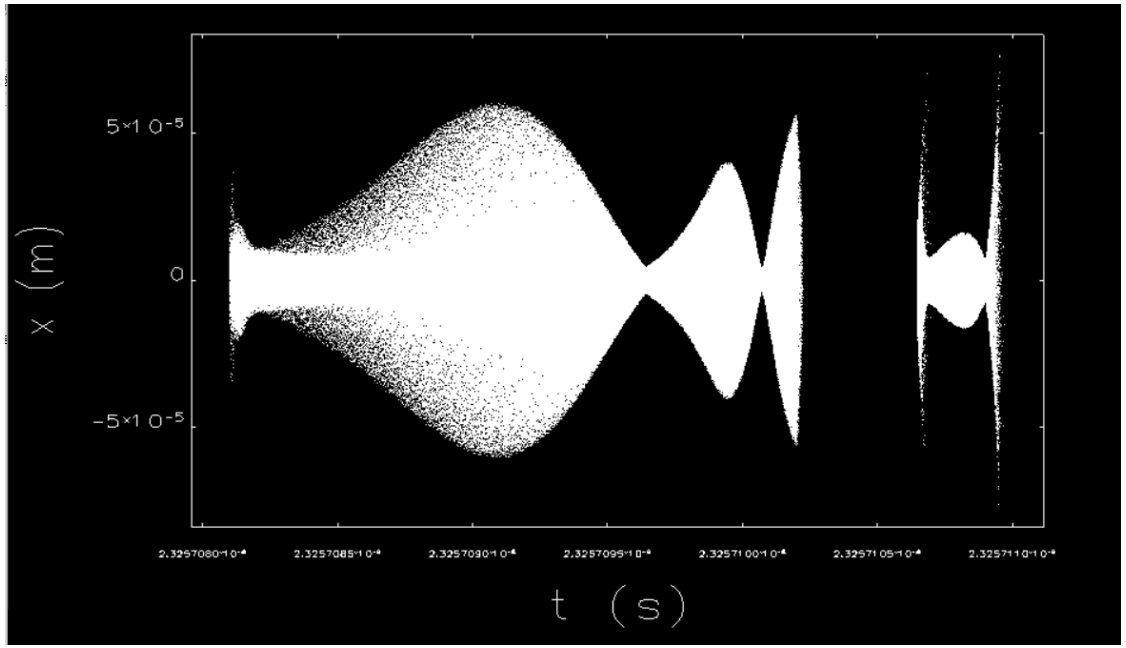
Progress on Linac

PWFA scheme

- Laser shaping @ electron gun (baseline) + bunch compressor
  - Two laser per electron gun → two beam (baseline)
  - (One laser per electron gun)*2 → two beam & merge (energy jitter, under consideration)
  - Space charge →Longitudinal deformation & longitudinal-transverse coupling
- Longitudinal modulation @ transport line (prospect) + bunch compressor
  - Nonlinear magnet modulation (under optimization)

@Guan SHU

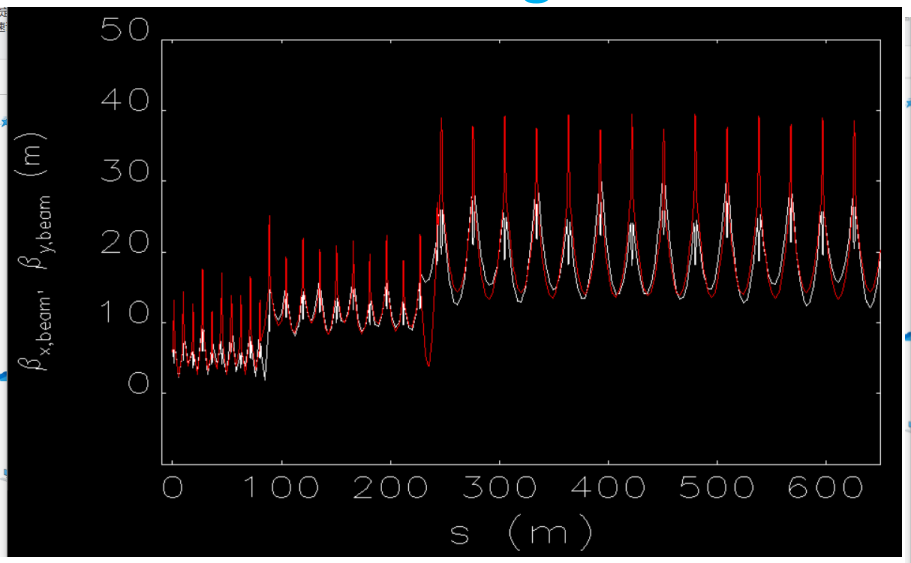


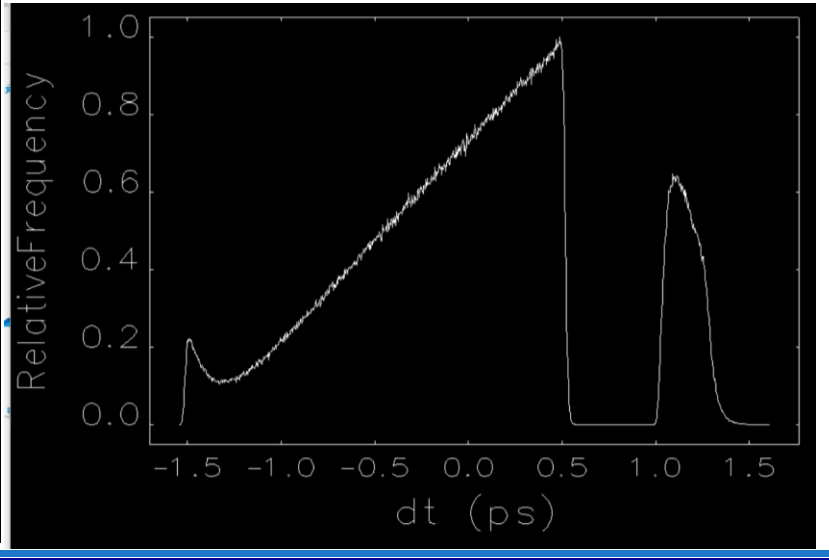


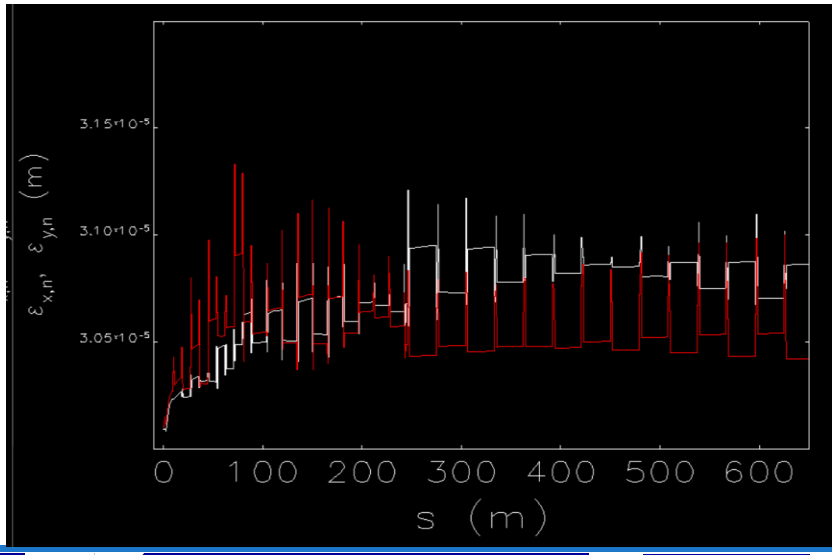
Progress on Linac

PWFA scheme

- Main Linac
  - Only acceleration: the longitudinal shape could be almost maintained
    - ✓ Short-range longitudinal wakefield + high bunch charge → large energy spread
    - ✓ FFS require small energy spread
  - Compressor
    - ✓ Long bunch length beam acceleration + bunch compressor(4~5GeV) + short bunch length beam acceleration
    - ✓ **Longitudinal deformation**







Other consideration

Two-bunch acceleration

➢Bunch space

- Collider ring 650 MHz, booster 1300MHz, Linac 2860 MHz
  - ✓Common frequency: f0=130 MHz/n
  - ✓Bunch space f_bunch=k*f0
  - ✓SHB frequency
    - ☐ f_shb1=m1*f_bunch
    - ☐f_shb2=m2*f_shb1
  - ✓f_linac=N*f_shb2
- **If RF gun is used, the bunch space is more flexible**

	frequency		Multiple	Period	
Common frequency	13	MHz	1	76.9231	ns
Two bunch	13	MHz	1	**76.9231**	ns
SHB1	143	MHz	11	6.9930	ns
SHB2	572	MHz	44	1.7483	ns
LINAC	2860	MHz	220	0.3497	ns
Booster	1300	MHz	100	0.7692	ns
Ring	650	MHz	50	1.5385	ns

➢Energy

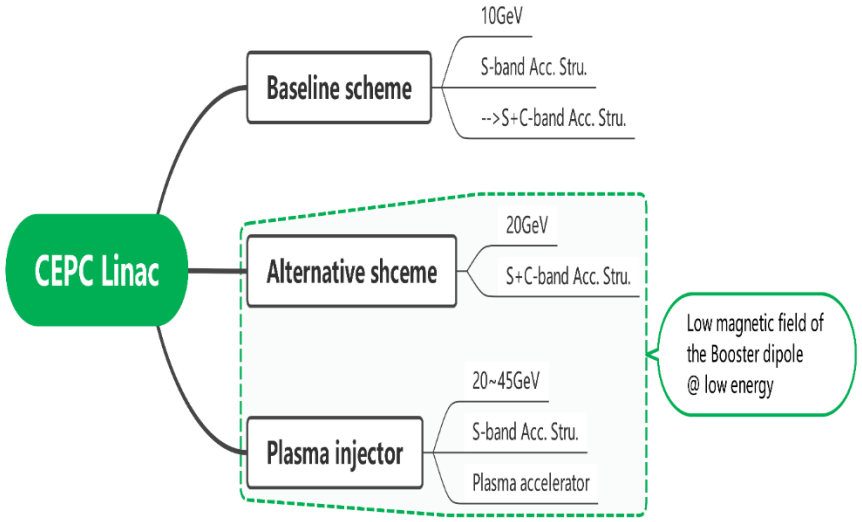
- SLED timing for energy compensation
- BPM can distinguish the orbits of the two bunch
  - ✓energy measurement and orbit correction

➢Positron source

- Thermal Stress/shock wave effect

➢Difficult, possible

- beam commissioning
- LLRF
- BPM

Summary

- The design of different schemes of CEPC Linac is continuous improving (new requirements).
- The low emittance baseline scheme and alternative scheme can meet the requirements.
- The PWFA scheme was proposed. There is still a certain distance from the goal, and more effort and new methods are needed.