CLIC Drive Beam Injector Design Update

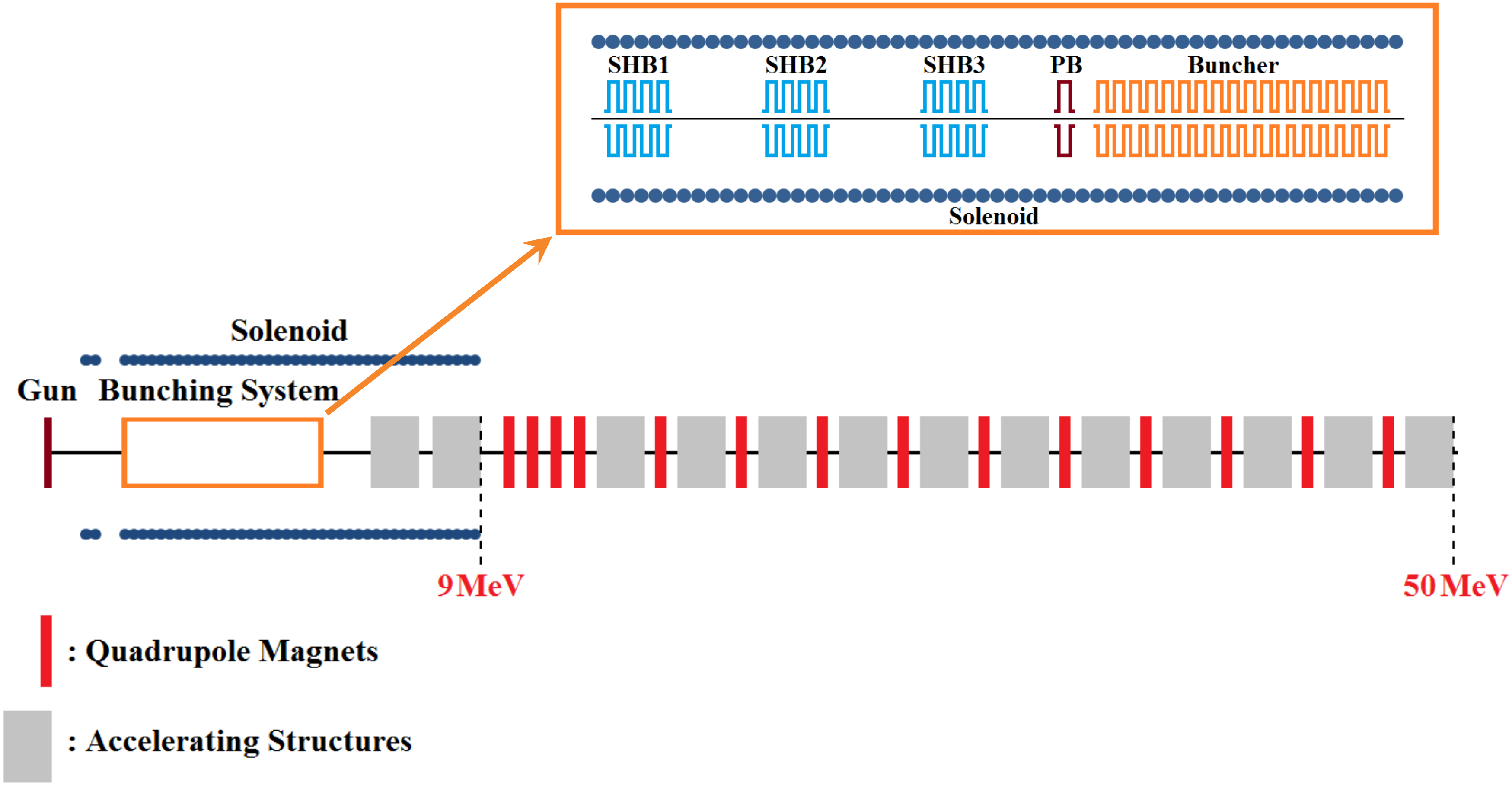
Shahin Sanaye Hajari

1. Institute For Research in Fundamental Sciences (IPM), Tehran, Iran
2. CERN, Geneva, Switzerland

Contents

1 Injector layout and the latest results

1.1 Injector Layout



1 Injector layout and the latest results

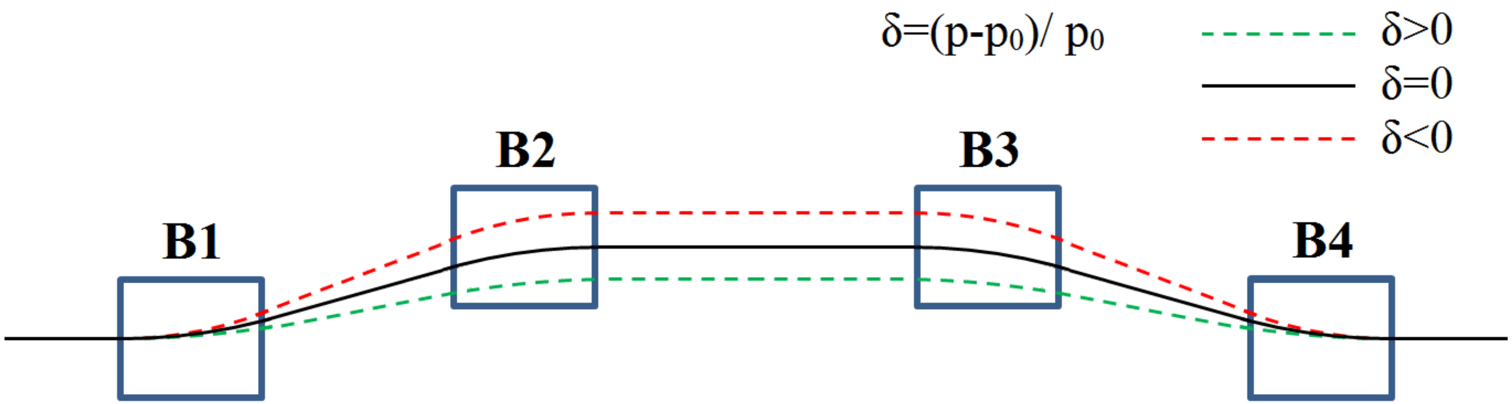
1.2 Latest results

	Parameters	Current value	Target value
Longitudinal	RMS bunch length	3 mm	3 mm
	RMS energy spread	0.530 MeV	< 0.5 MeV
	Satellite population	2.6%	As less as possible
Transverse	Normalised emittance	35 mm-mrad	<100 mm-mrad
	Average solenoidal field	530 gauss	As small as possible

Beam loss at chicane: 4%

2 Optimisation of the magnetic chicane

2.1 Bunch compression



$$\begin{cases} z_f = z_i + R_{56}\delta_i \\ \delta_f = \delta_i \end{cases}$$

$$\Downarrow$$

$$\langle z_f^2 \rangle = \langle z_i^2 \rangle + 2R_{56}\langle z_i\delta_i\rangle + R_{56}^2\langle \delta_i^2 \rangle \quad \Rightarrow$$

$$(R_{56})_{optimum} = -\frac{\langle z_i\delta_i\rangle}{\langle \delta_i^2\rangle}$$

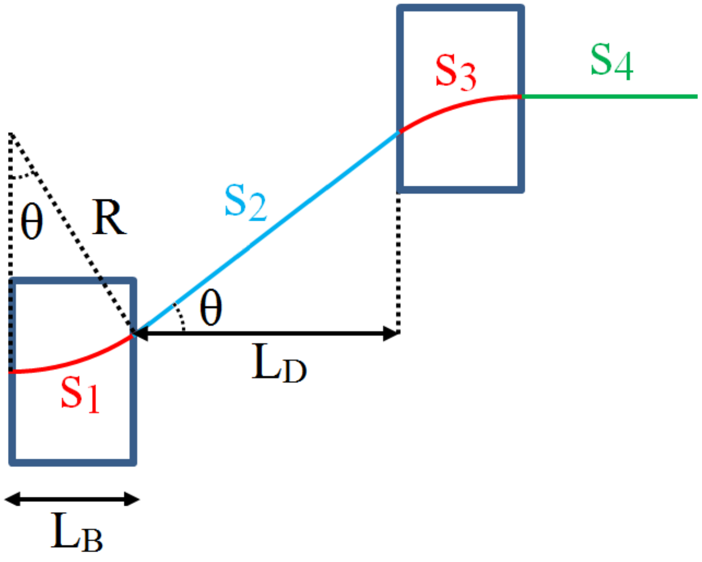
$$\langle z_f^2 \rangle_{min} = \langle z_i^2 \rangle - \frac{\langle z_i\delta_i\rangle^2}{\langle \delta_i^2\rangle}$$

2 Optimisation of the magnetic chicane

2.1 Bunch compression

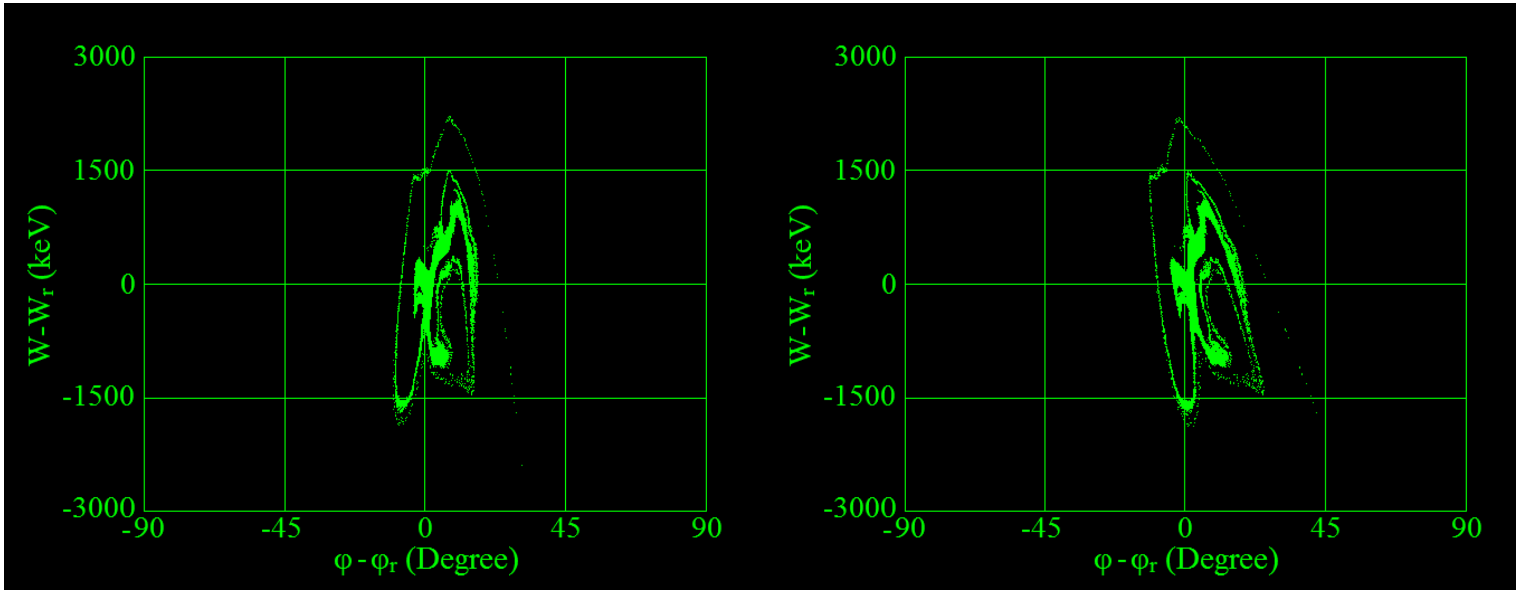
$$L(\delta) = 2\left[2\frac{p_0(1+\delta)}{eB}\sin^{-1}\frac{L_B eB}{p_0(1+\delta)} + \frac{L_D}{\sqrt{1-\left(\frac{L_B eB}{p_0(1+\delta)}\right)^2}} + s_4\right]$$

$$\begin{aligned} z_f - z_i &= L(\delta) - L(0) \\ &= R_{56}\delta + T_{566}\delta^2 + U_{566}\delta^3 \end{aligned}$$



2 Optimisation of the magnetic chicane

2.1 Bunch compression

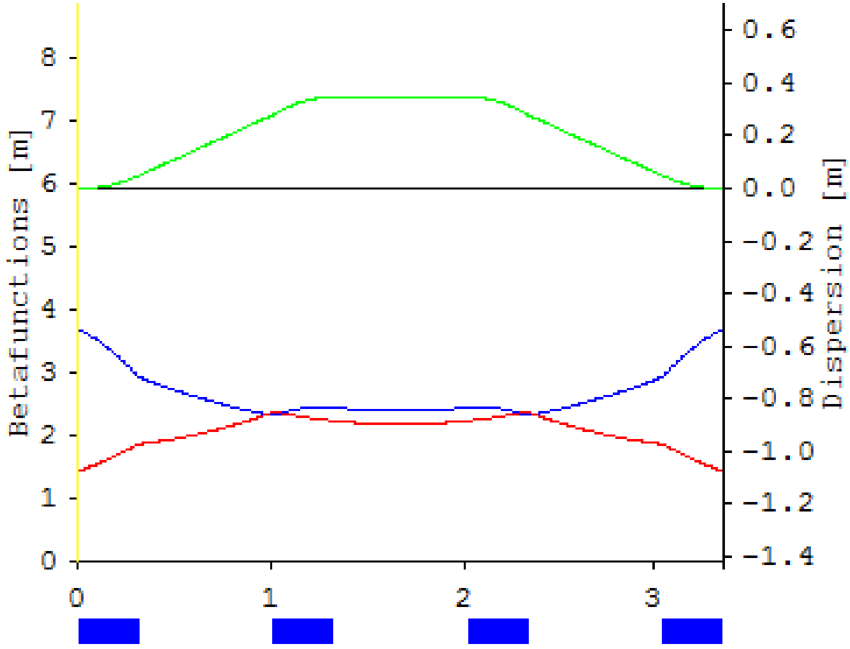


Before chicane After chicane

$(R_{56})_{optimum} = -20.0\ cm \quad \Longrightarrow$ **Bunch length reduction: ~ 20 %**

2 Optimisation of the magnetic chicane

2.2 Transvers plane and chicane parameters

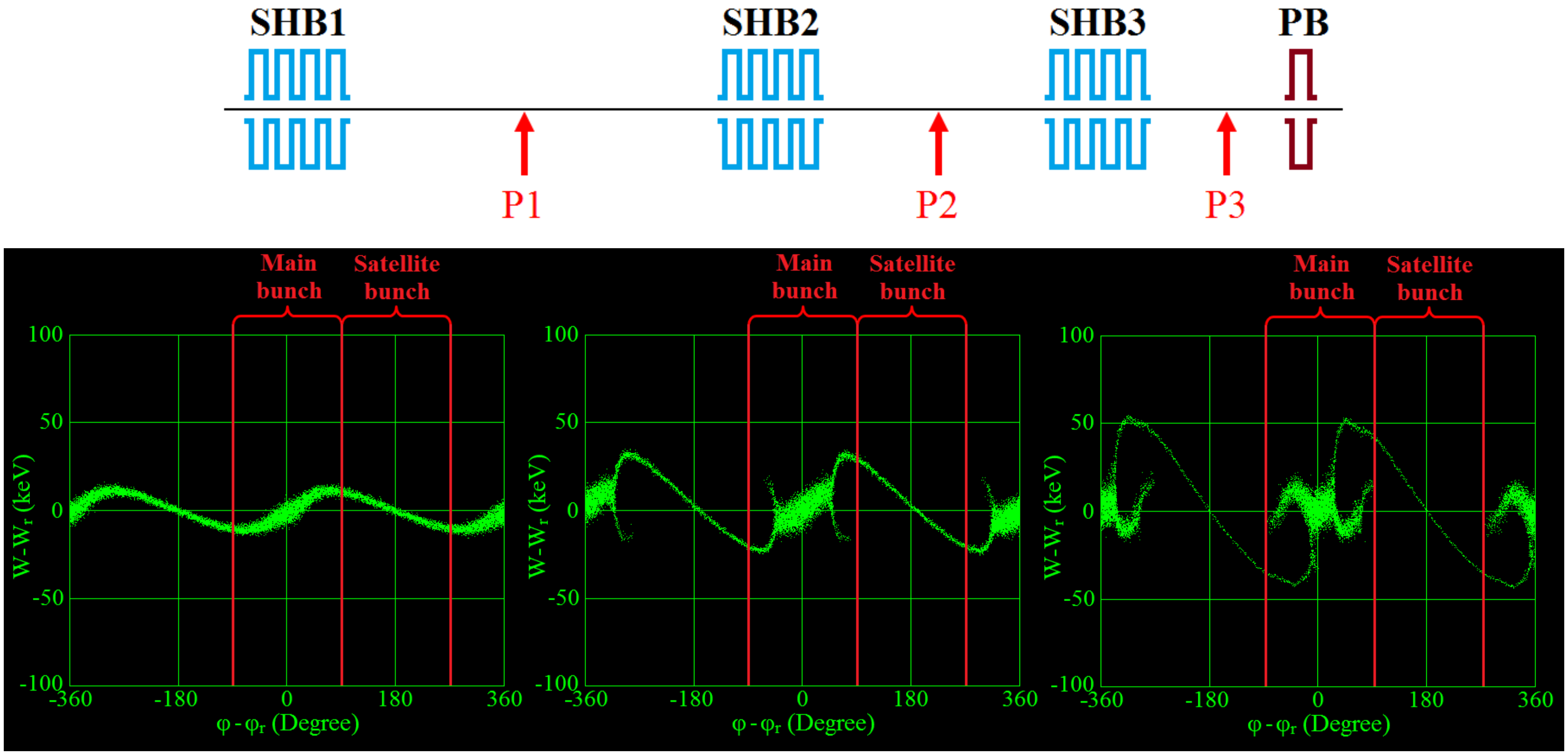


Parameter	Value
Dipole field	0.186 T
Dipole length	29.5 cm
Drift length	70 cm
Bending angle	18.5^{o}

$$L(\delta) = 330 - 20.0\delta + 33.1\delta^2 - 49.8\delta^3 + O[\delta]^4$$

3 Chicane and the injector overall performance

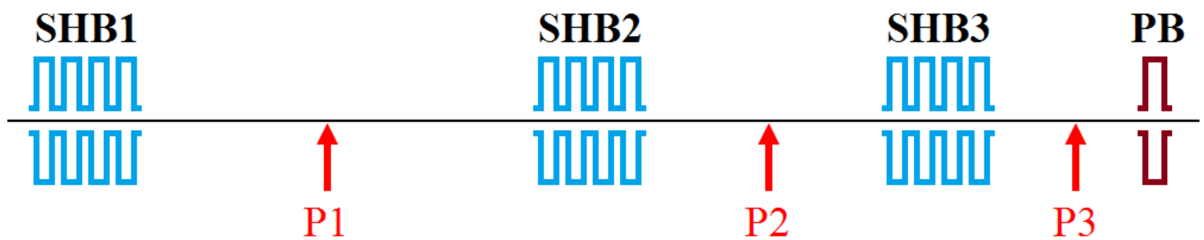
3.1 Satellite population

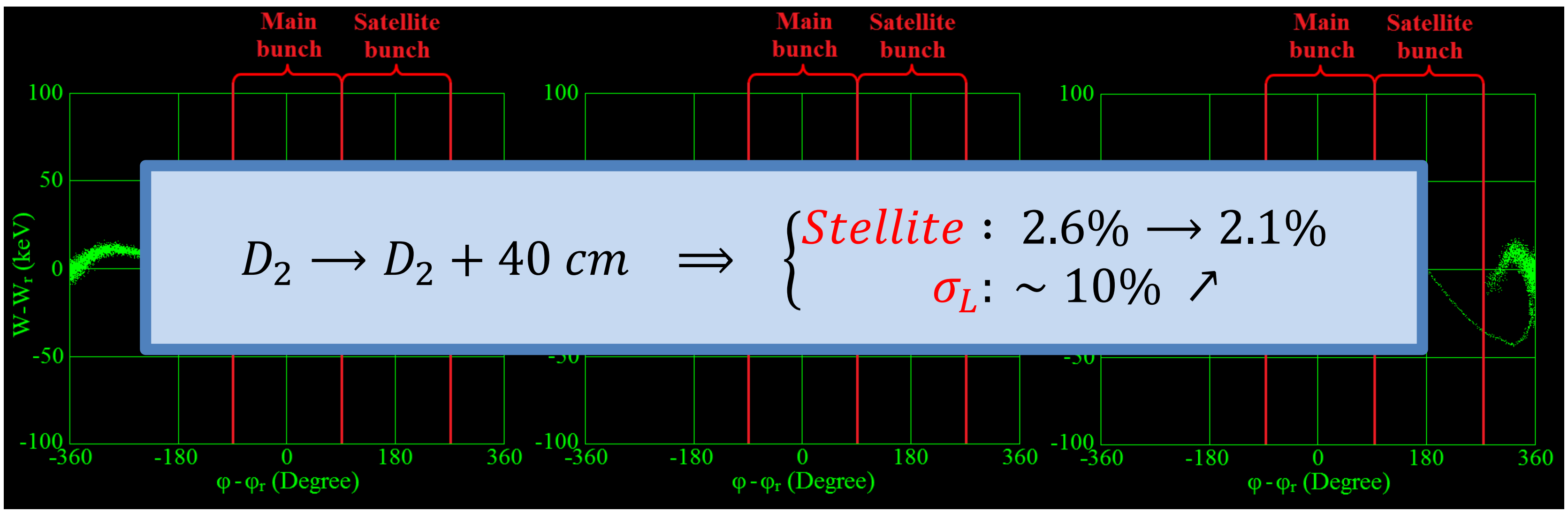


At P1 At P2 At P3

3 Chicane and the injector overall performance

3.1 Satellite population





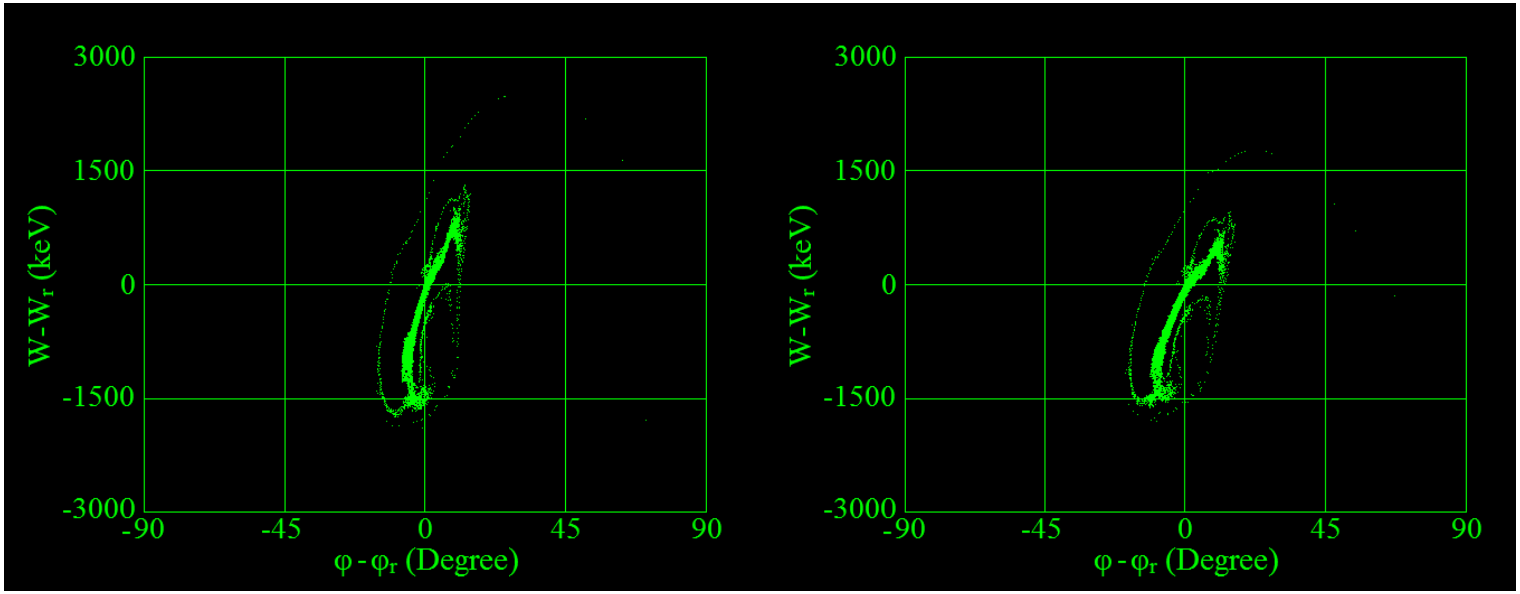
$$D_2 \longrightarrow D_2 + 40\ cm \quad \Longrightarrow \quad \begin{cases} Stellite: \ 2.6\% \longrightarrow 2.1\% \\ \sigma_L: \sim 10\% \nearrow \end{cases}$$

At P1 At P2 At P3

3 Chicane and the injector overall performance

3.2 Bunch length and energy spread correlation

After first accelerating structure (6 MeV)



40^o off-crest

$$\begin{cases} \sigma_L = 4.7\ mm \\ \sigma_W = 0.647\ MeV \end{cases}$$

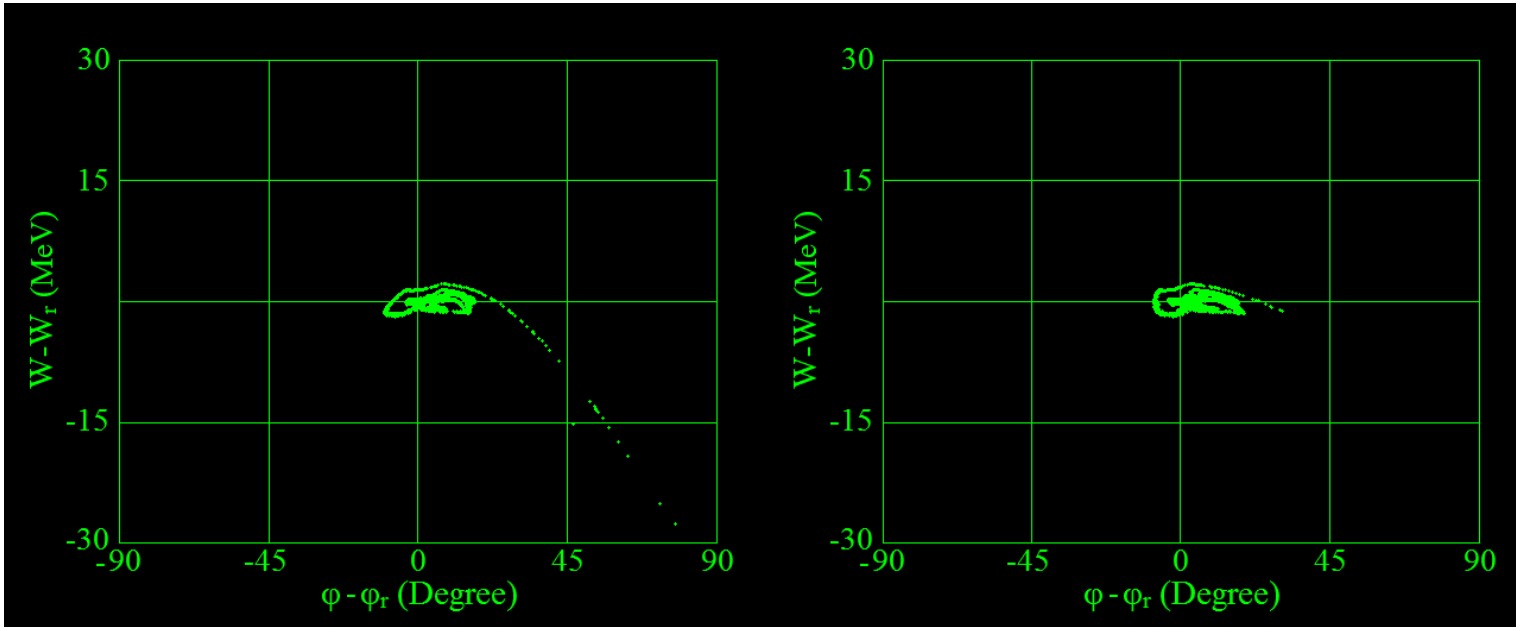
20^o off-crest

$$\begin{cases} \sigma_L = 5.5\ mm \\ \sigma_W = 0.553\ MeV \end{cases}$$

3 Chicane and the injector overall performance

3.3 Beam loss at chicane

$$\sigma_L: 10\% \nearrow \quad \Longrightarrow \quad \frac{\sigma_W}{W_{av}} < 1\% \quad \Longrightarrow \quad No\ loss$$



Beam loss at chicane: 4% ⟶ 0.1%

4 Fourth SHB

4.1 Satellite reduction motivation

Satellite bunches:

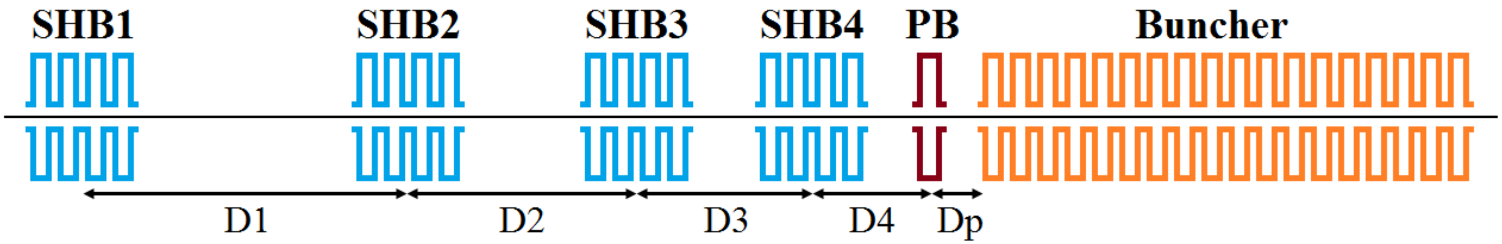
- drive beam power efficiency. ⟹ **Satellite cleaning system**
- unwanted radiation

Model	Satellite population
CDR version	4.9%
Current model	2.1%
4 SHB	1.0%

Number of SHB	Satellite population
1	~14%
2	~5%
3	~2%
4	~1%

4 Fourth SHB

4.2 Sub-harmonic bunching system parameters



4SHB

Cavity	Distance to next cavity	Voltage
SHB1	255 (cm)	13 (kV)
SHB2	145 (cm)	25 (kV)
SHB3	85 (cm)	35 (kV)
SHB4	50 (cm)	50 (kV)
Prebuncher	20 (cm)	45 (kV)

3SHB

Cavity	Voltage
SHB1	15 (kV)
SHB2	30 (kV)
SHB3	45 (kV)
Prebuncher	60 (kV)

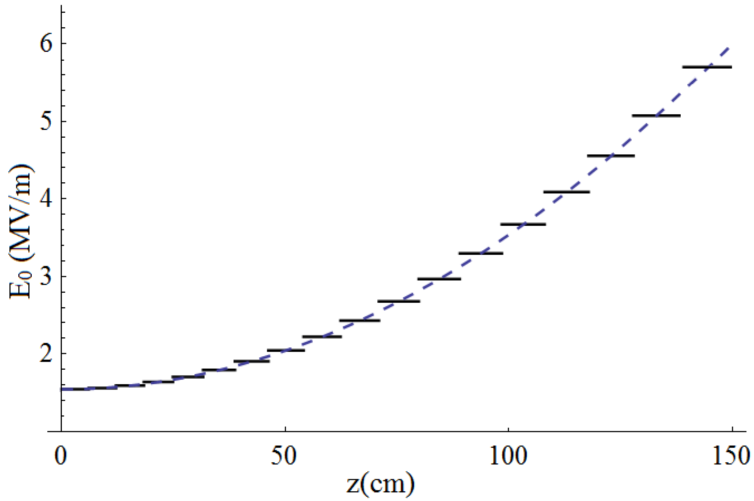
5 Conclusion

- ✓ By optimising the magnetic chicane to act as a bunch compressor as well as phase space cleaner the allowed bunch length at the end of injector will be 20% longer. This results in:
  - ➢ Satellite population reduction
  - ➢ Beam loss reduction

- ✓ By using an additional SHB the Satellite population can be reduced to 1.0%.

Thanks for your attention.

TW Buncher: Beam Loss Reduction



Buncher parameter	Value
$E_{min}(MV/m)$	1.2
$E_{max}(MV/m)$	5.7
L(cm)	147
P(MW)	~20

Beam parameter	Value
$\sigma_L(mm)$	7.23
$\sigma_W(MeV)$	0.317
$W_{av}(MeV)$	2.38

Beam loss at magnetic chicane:
$\longrightarrow$ **3.9%**

Options for the Solenoid Channel: Emittance Growth