HZB Helmholtz Zentrum Berlin

B*ERL*inPro

Status of the Optics of B*ERL*inPro

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Overview

B*ERL*inPro funding approval October 2010 – 25.8 Mio € / 5 years
Project start: January 2011
Detailed cost estimation spring 2011 – need for severe cost reduction
First MAC-meeting May 17/18 –
down grading of project goals recommended

Recommendations relevant for optics:

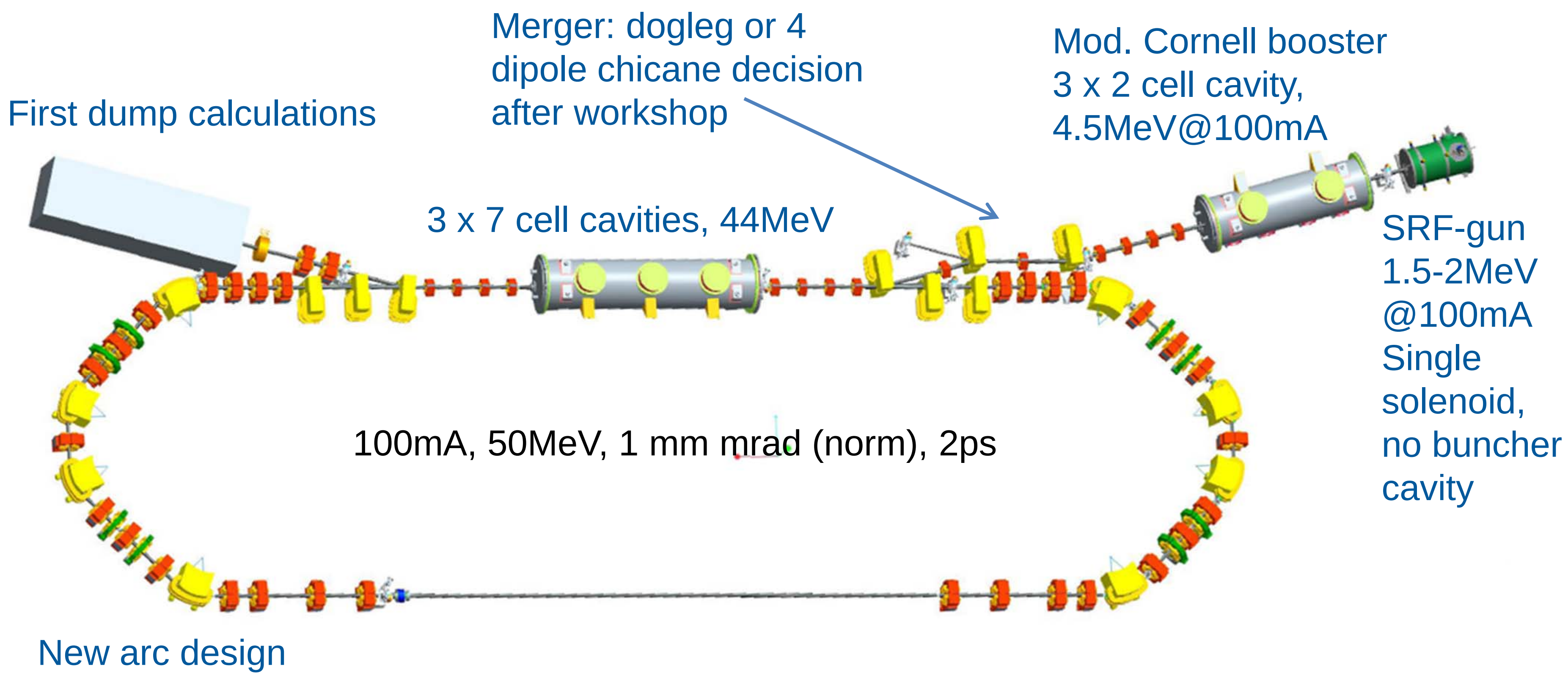
- 50MeV (100MeV) – reduces radiation protection needs by ~50%
- only three (five) booster cavities, staying at 5-10MeV
- initially only two transmitters (possible upgrade to three, ~4Mio€)
- no cathode laser pulse shaping (~1Mio€)

Since then work on adapted design – close to finalization CDR due end of 2011

Contents

- General machine parameters / layout
- Gun project / Gaussian cathode laser profile / laser pulse length
- Effect of reduced number of booster cavities
- Bunch compression in injector
- Merger decision still open / results for chicane merger
- Impact of BBU considerations
- Modified arc layout
- Ways to skip the HE chicane
- Lookout

General Machine Parameters / Layout



Minimal machine design / work on new cost estimates in progress
No space for second turn, experiment / no up-grade options

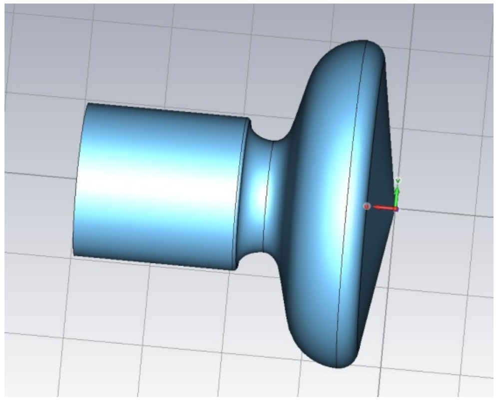
SRF Gun Project

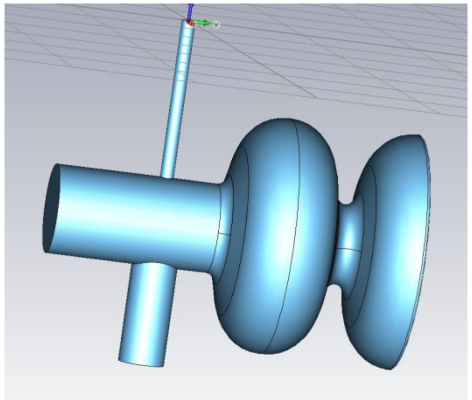
Gun0 - Just finished commissioning run with cavity 0.1 (April – August 2011)

Fully SC-Gun lead coated back wall
Got beam and did all planned measurements

Talks EuCARD-meeting, Ultra bright beams workshop, SRF 2011 and IPAC 2011, Polarized source workshop

Decision on final cavity shape still open
Started parameter studies to judge half-cell vs. 1.6 cell design:





Cathode Laser Profile – Gauss versus Flat Top

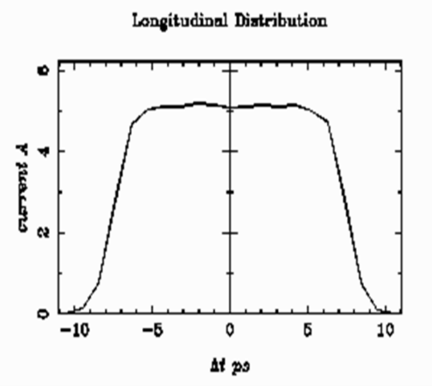
Same hardware, same phases, fields

Bunch current profiles at 8cm (behind cathode)

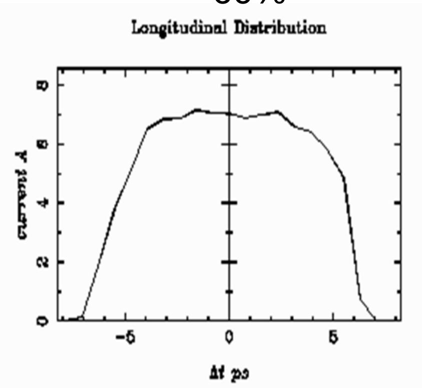
Difference in sliced Emittance

Laser profile

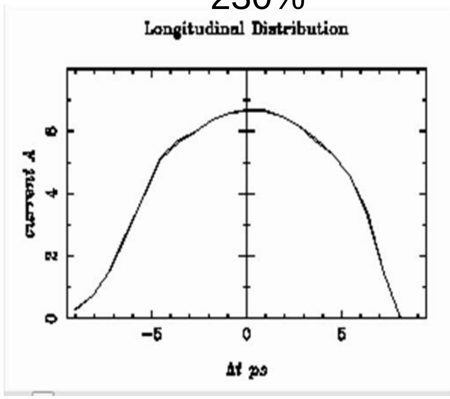
Flat top



60%

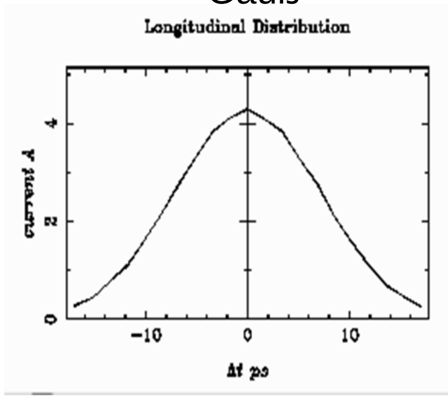


230%



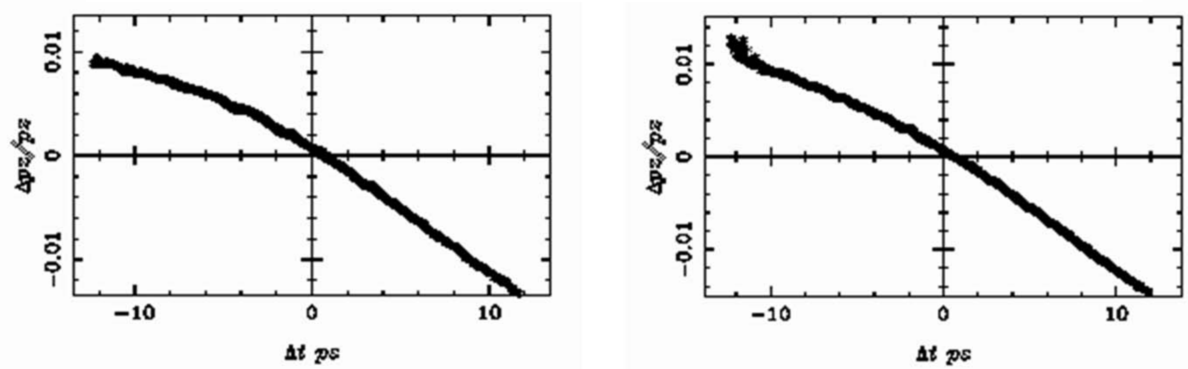
Laser profile

Gauß



Parameters behind the booster	**Flat Top Pulse**	**Gaussian Pulse**
Pulse [ps]	2-15-2 ps	7.2ps rms
Bunch length [mm]	1.61	1.66
DP [keV]	-39	-43
Emittance x,y [$\pi\mu$rad]	0.90/0.93	0.86/0.87

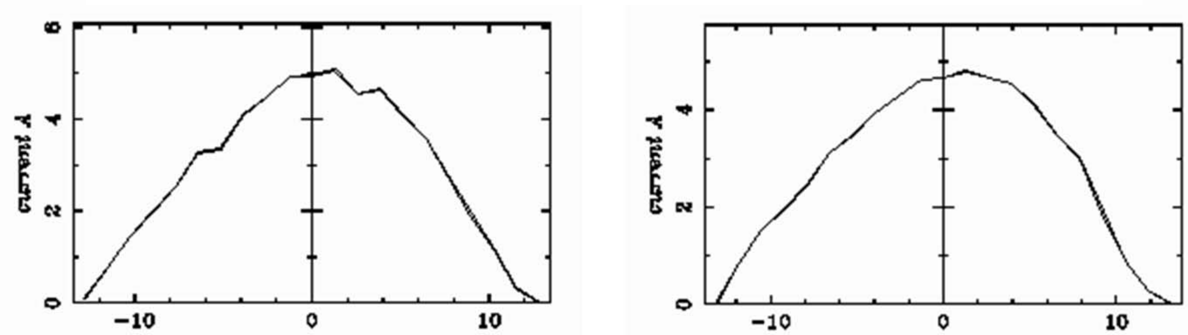
Longitudinal phase space behind booster



Longitudinal current distribution behind booster

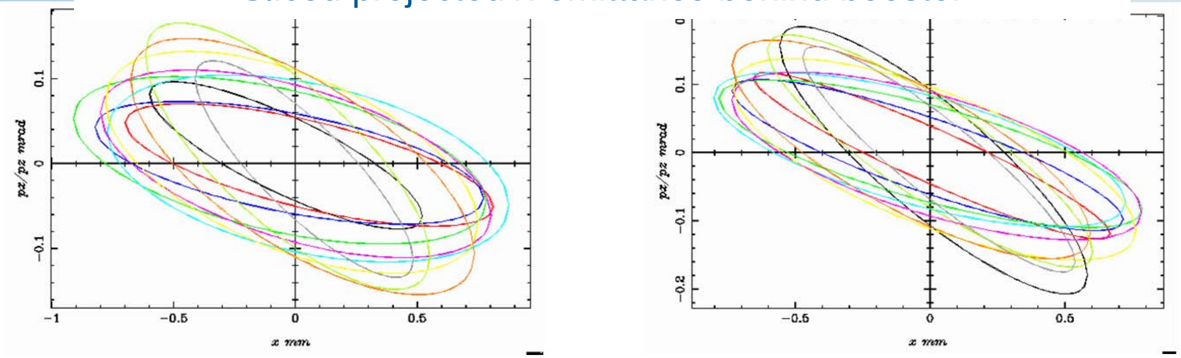
Flat top

Gauß



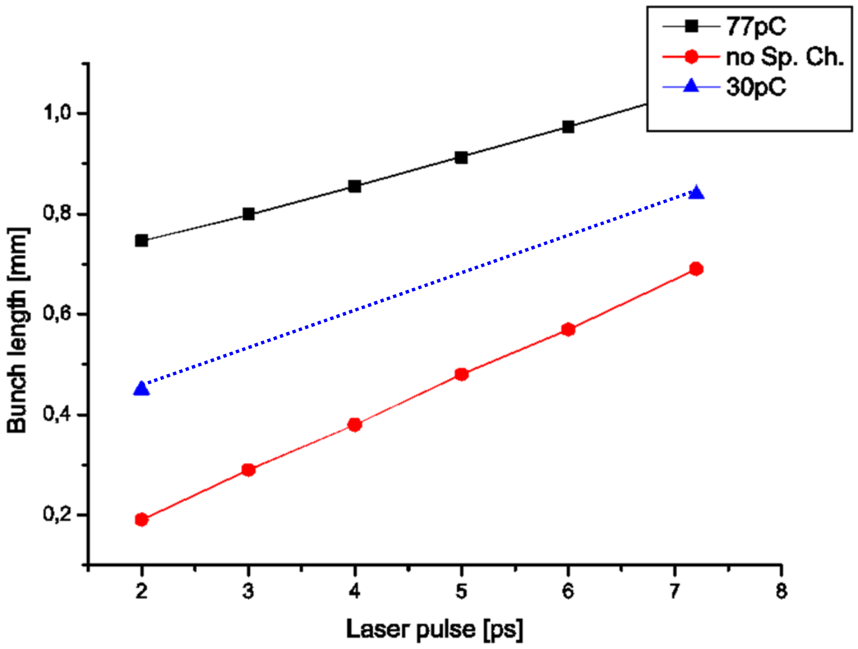
Sliced projected x-emittance behind booster

Difference in sliced emittance 300%



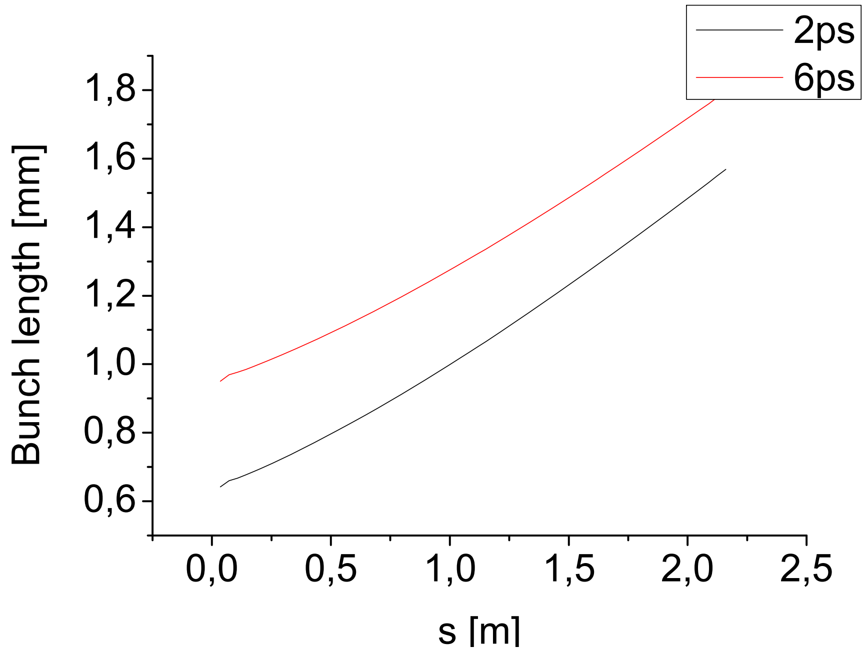
Difference in sliced emittance 270%

The bunch length in the SRF gun is significantly shorter than the laser pulse length, due to velocity bunching. Space charge forces dominate the laser pulse length.



Bunch length as a function of the laser pulse length

Without space charge, the bunch length is proportional to the laser pulse.

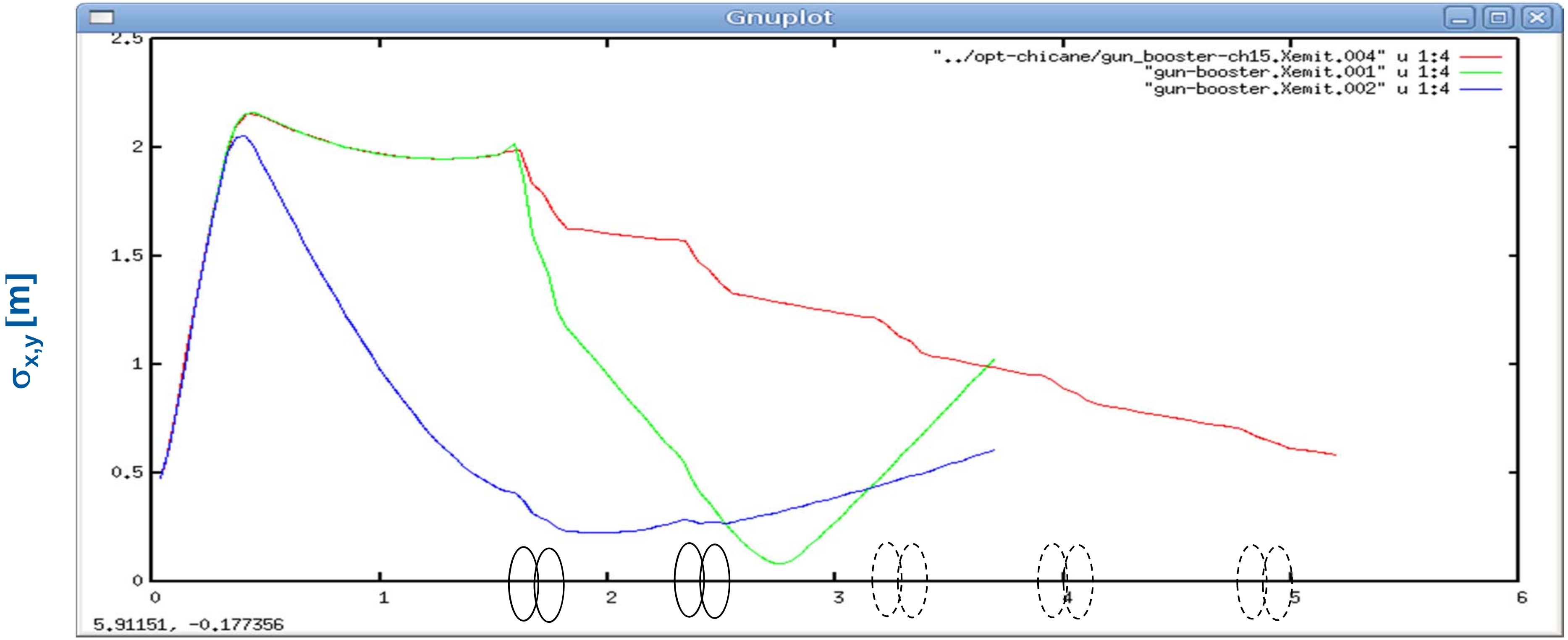


Bunch length development cathode to booster

In front of the booster the bunch is ~10% shorter for a laser pulse of 2ps instead of 6ps.

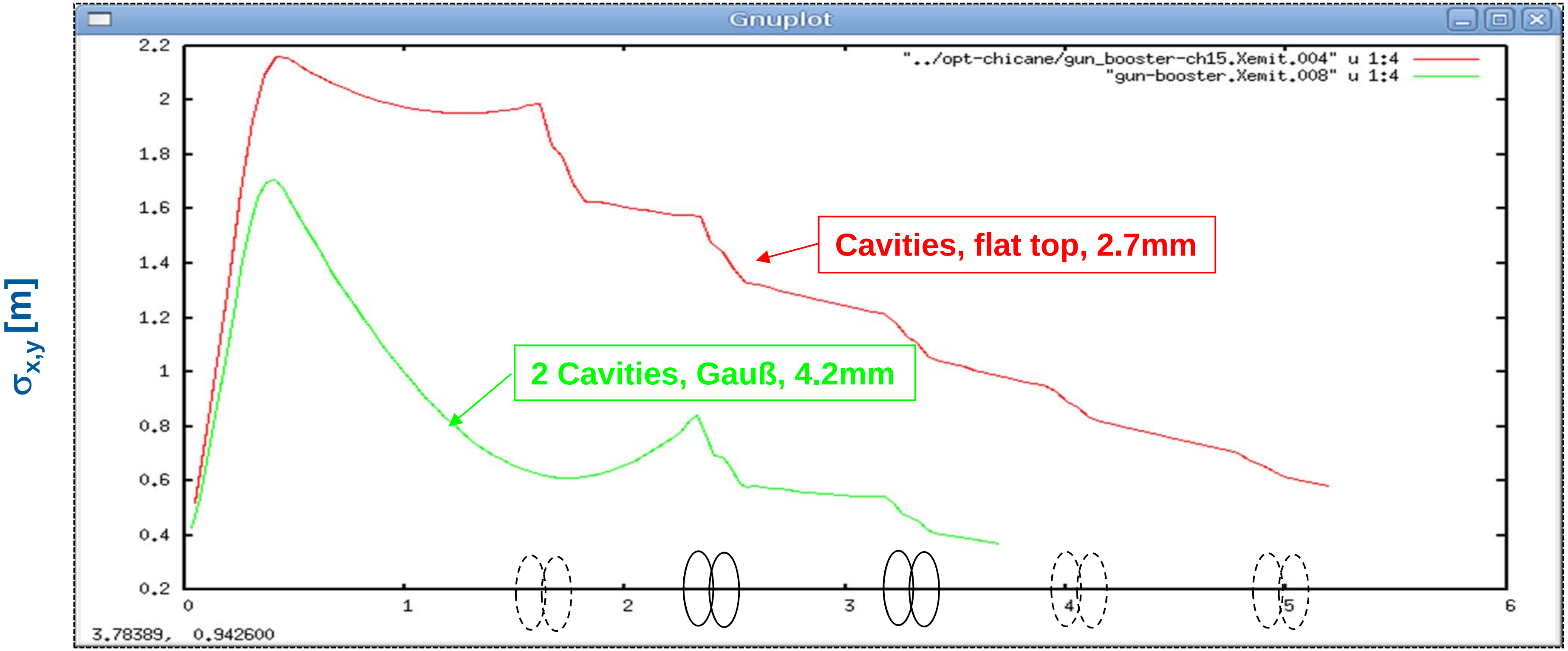
Increased RF-focusing –
not completely compensable by solenoid

Cavities	Puls	Solenoid [T]	Emittanz [μrad]	Länge [mm]
5	Flat Top	0.063	0.73	2.7
2	Flat Top	0.063	1.3	2.5
2	Flat Top	0.072	0.9	2.6



Similar beam size development achieved at cost of increased bunch length when using two down stream cavities

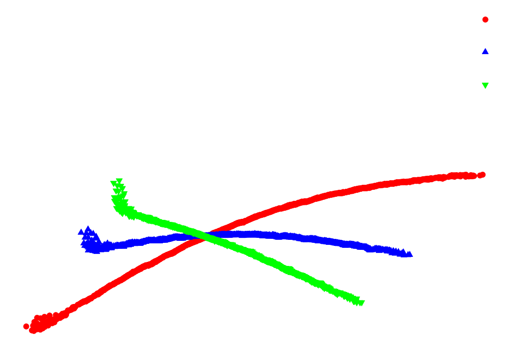
Cavities	Pulse	Solenoid [T]	Emittance [µrad]	Length [mm]
5	Flat Top	0.063	0.73	2.7
2	Gauß	0.070	0.70	4.2



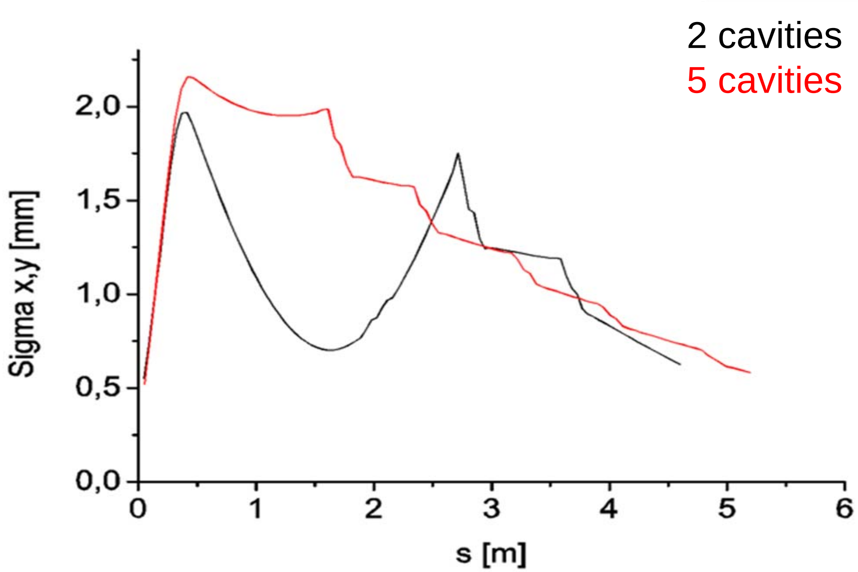
Usage of first cavity for energy chirp

- First cavity will have only 9kV transmitter
- Field without beam loading
  enough to energy chirp the bunch
- Bunch length behind booster : 0.3 – 5mm

Longitudinal phase space behind booster

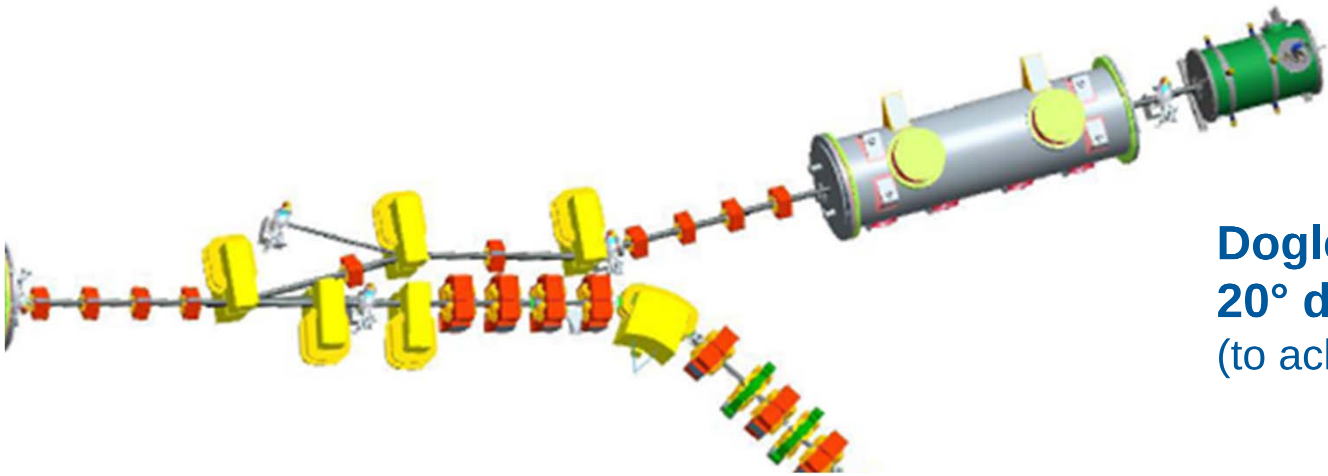


Beam size for 2 and 5 cavities



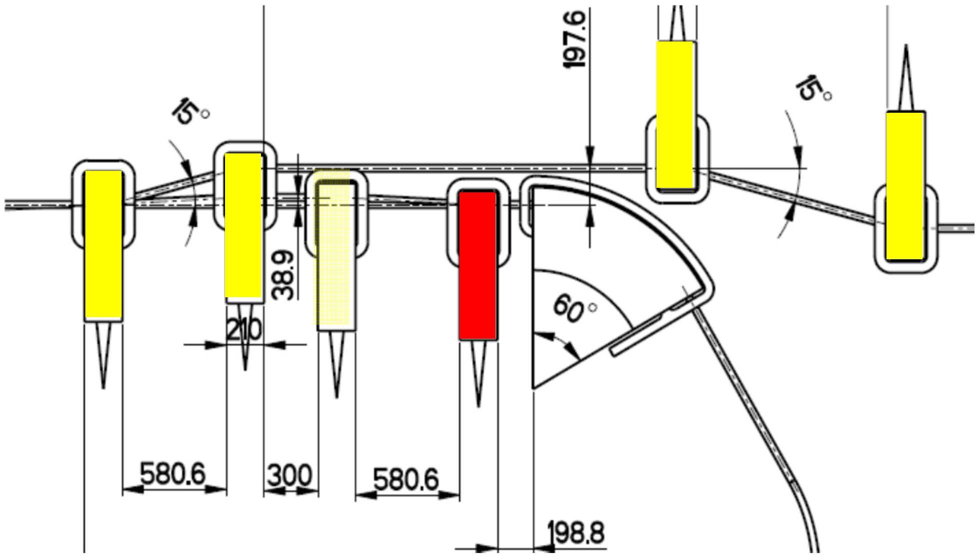
	Behind Booster
Emittance [mm mrad]	0.86/0.87
Bunch length [mm]	1.7

Merger: Decision still open Dogleg ⇔ Chicane



Dogleg
20° dipoles
(to achieve adequate R56)

4 Dipole Chicane
15° dipoles
(to achieve adequate R56)



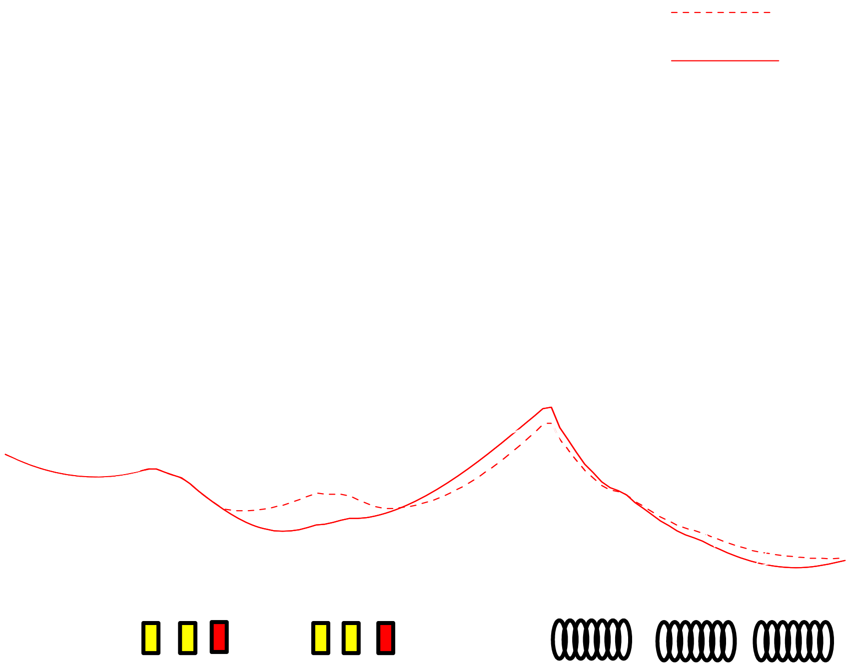
Merger Dogleg versus 4 Dipole Chicane

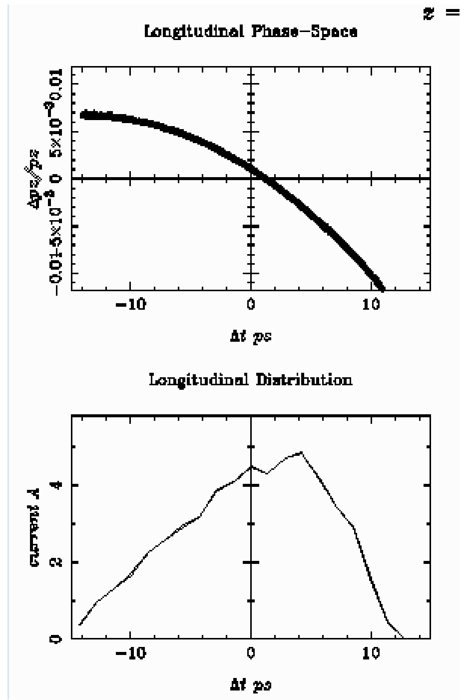
Dogleg	Chicane
Performance	
Emittance < 1 mm mrad @77pC, 2-3/6ps	
R56 for bunch compression ok	
Geometry	
No interference with high energy beam line	Less building space
Commissioning	
Strong quadrupoles in dispersive section	No (higher order) dispersion
Depends on quadrupole optimization via sliced emittance measurement	Works without/few quads

With 2 quadrupoles: εx,y = 0.97 / 0.97

Without quadrupoles: εx,y = 1.67 / 0.81

Bunch length 6ps

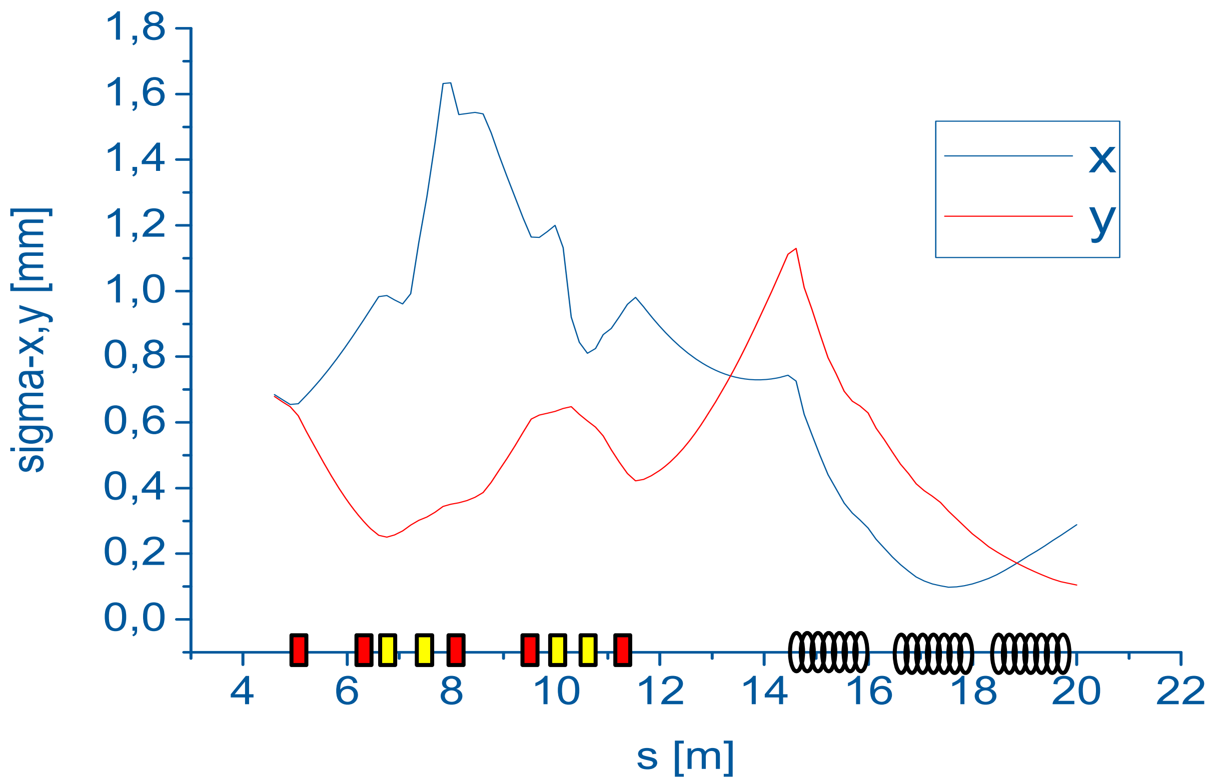


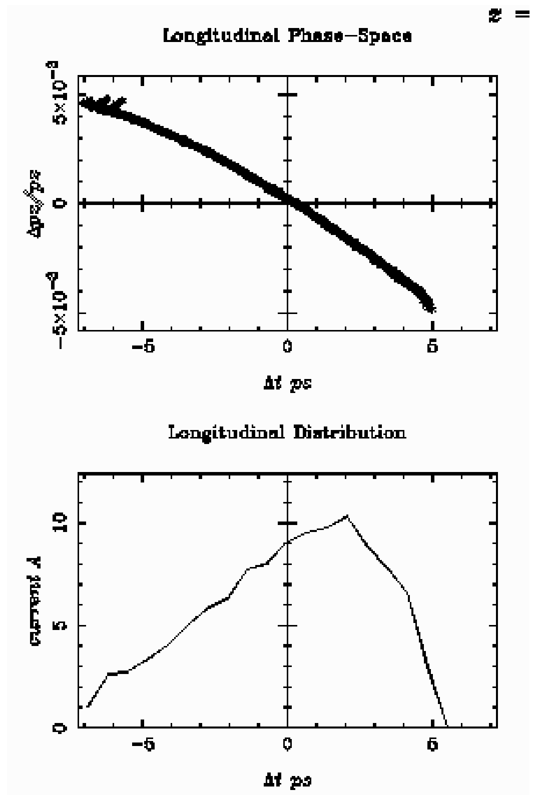


Long. phase space behind linac – arc compression to 2ps

With 5 quadrupoles: εx,y = 0.94/1.1

Bunch length 3ps





Long. phase space behind linac – arc compression to few 100fs

BBU - Instability

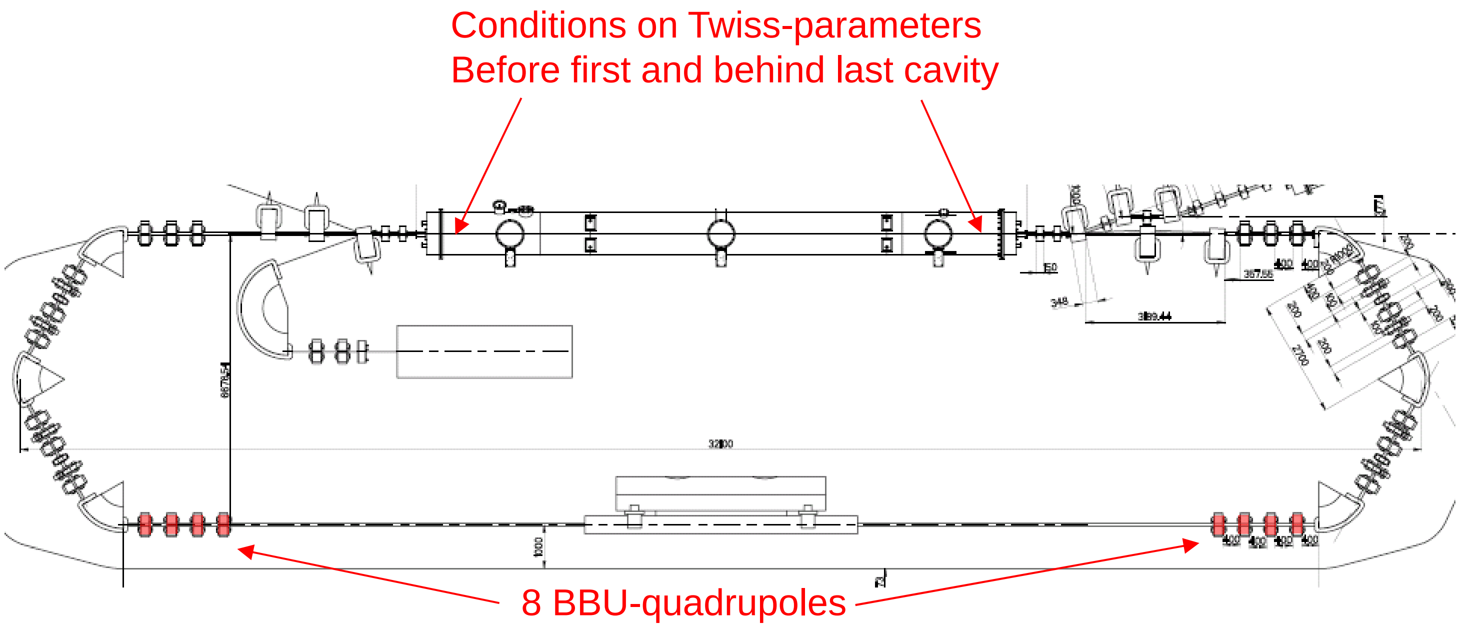
Two conditions to suppress BBU instability:

- phase advance recirculator

  => 8 quadrupoles in long straight section
- Shaping of beta functions in linac

(PhD theses: Yuriy Petenev)

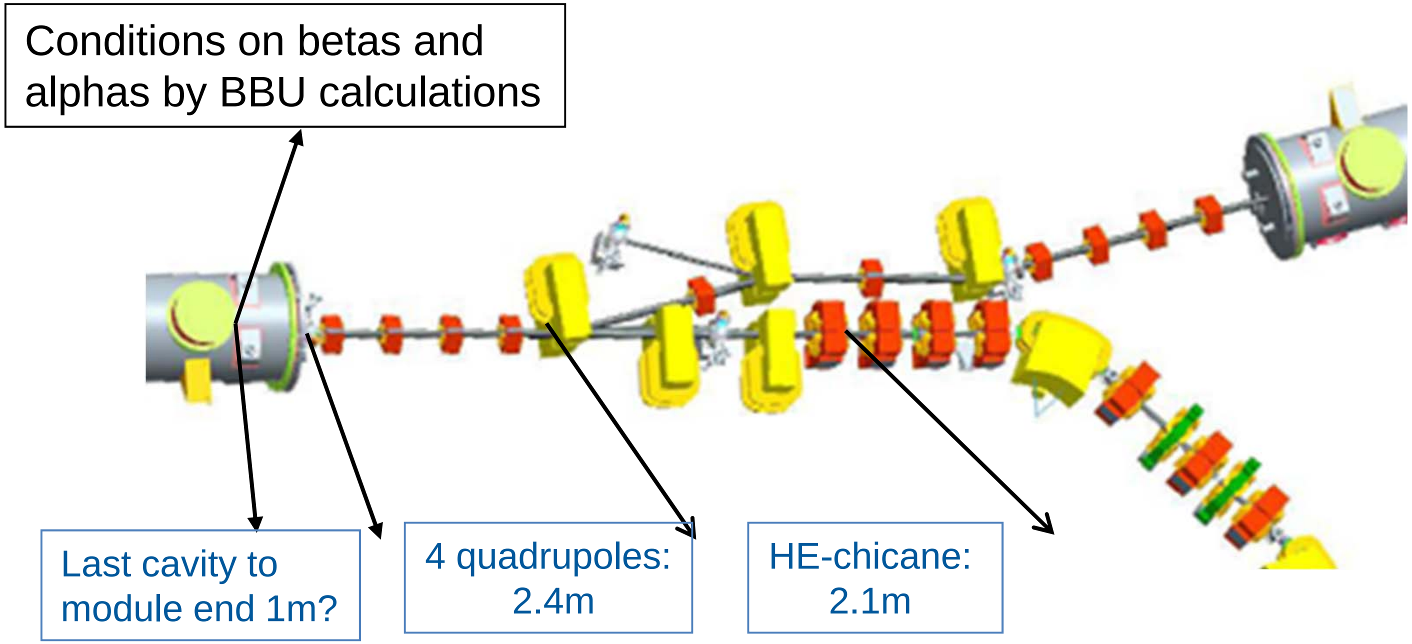
		βx	αx	βy	αy
Theory	Start	9.5	-1.8	2.5	-0.2
	End	1.1	-0.5	4.5	-1.0
Small average betas	Start	5.0	0.5	5.0	0.5
	End	5.0	1.7	5.0	1.7



Return arc to linac

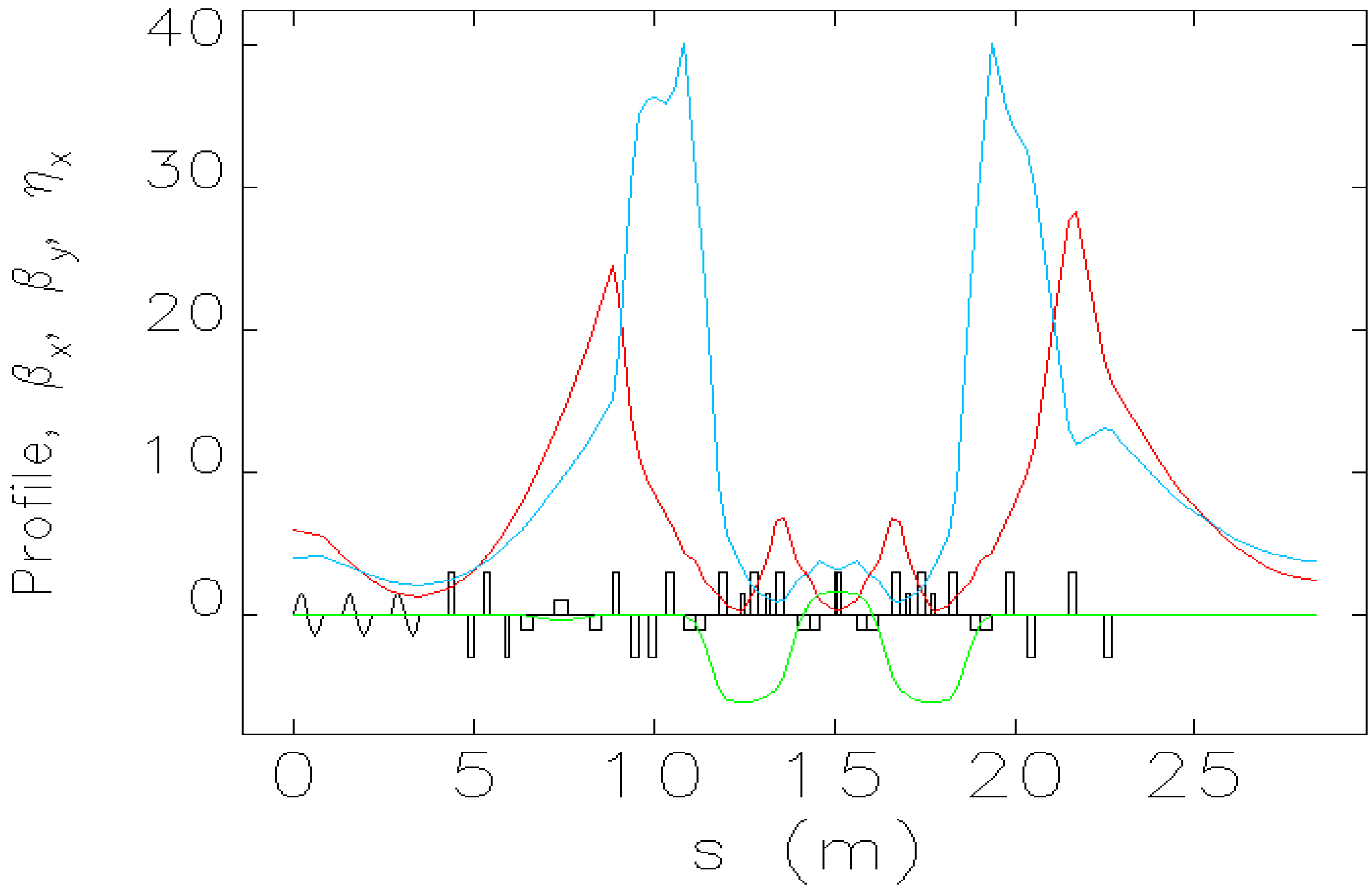
- BBU conditions at first cavity
- Low energy quadrupoles set by emittance compensation effect HE beam for large betas
- ~6m of un-tunable beta functions
  => matching problems

Solution: keep structure short / max. flexibility in arc



Return arc optics

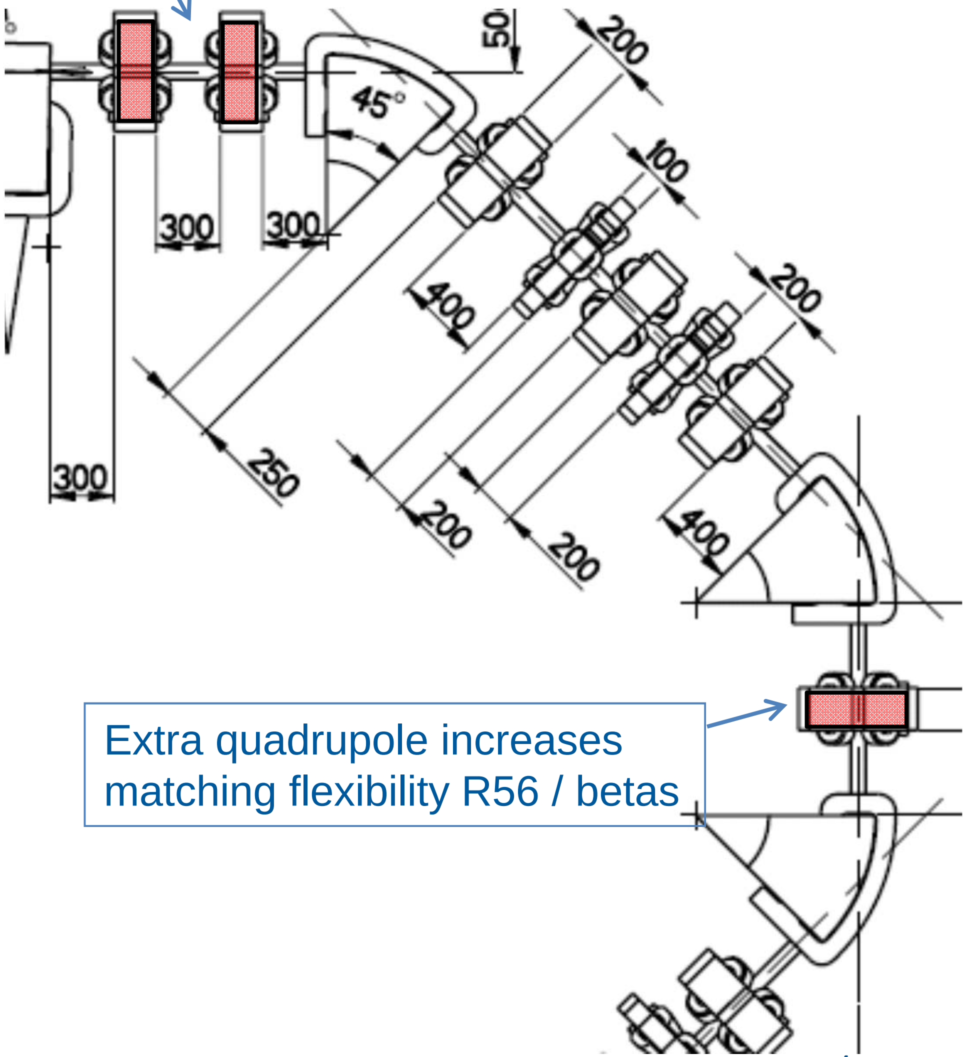
Possible optical solution for modifies BBU conditions
Low energy quadrupoles not powered



Number of quadrupoles to be determined

Arc comparison: 45° - 60° dipoles

Anforderungen		3x60°	4x45°
Dispersion	η–max	1.1m	0.6m
Compression	|R56|-max	0.2m	0.4m
BBU-Conditions	β's, α's 1. Cavity	Mit Quads	ok
Dipole	Form	Sektor	Rect.
Kleiner Biegeradius	ρ	1.0	0.76

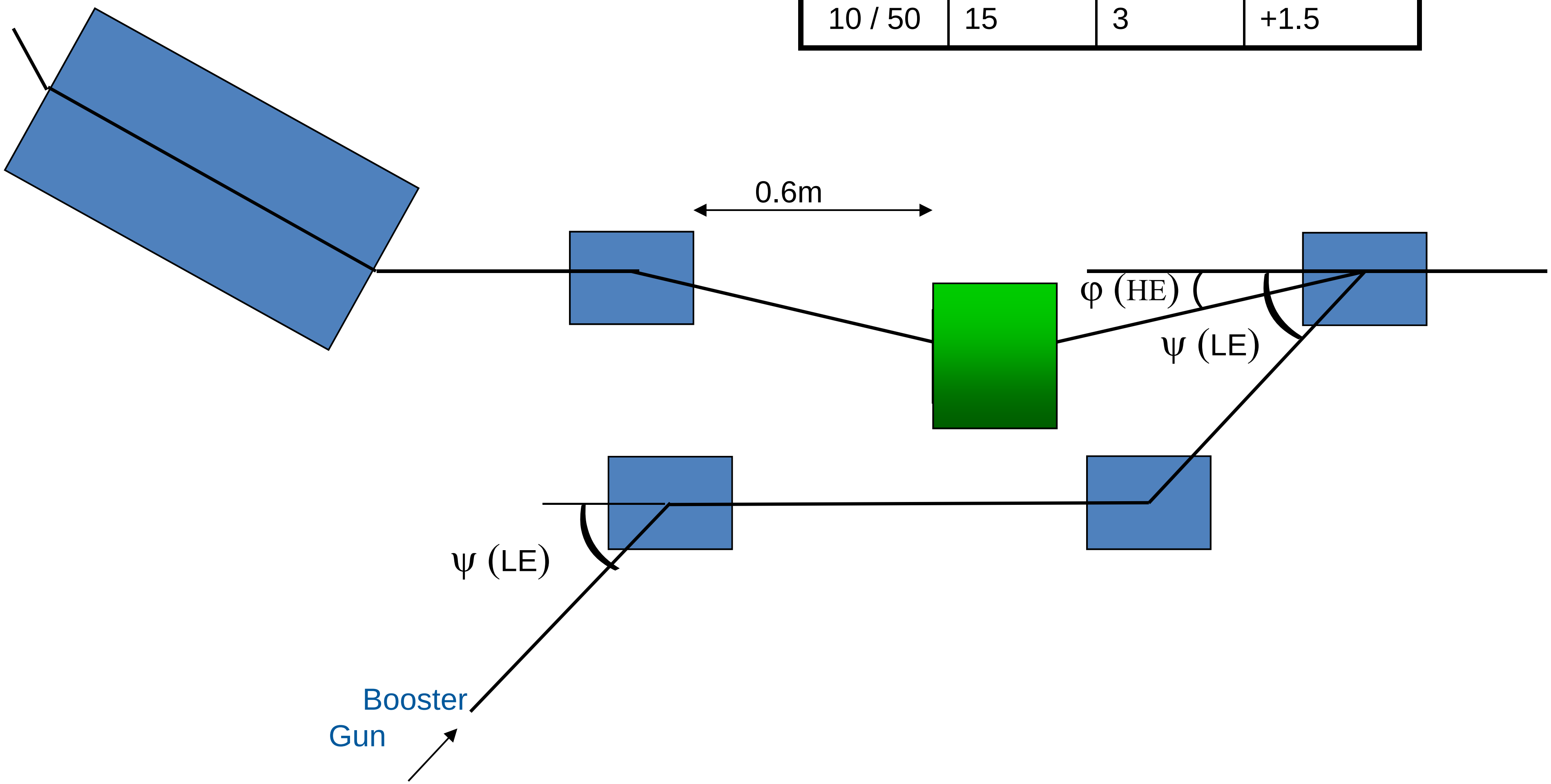


Extra quadrupole increases matching flexibility R56 / betas

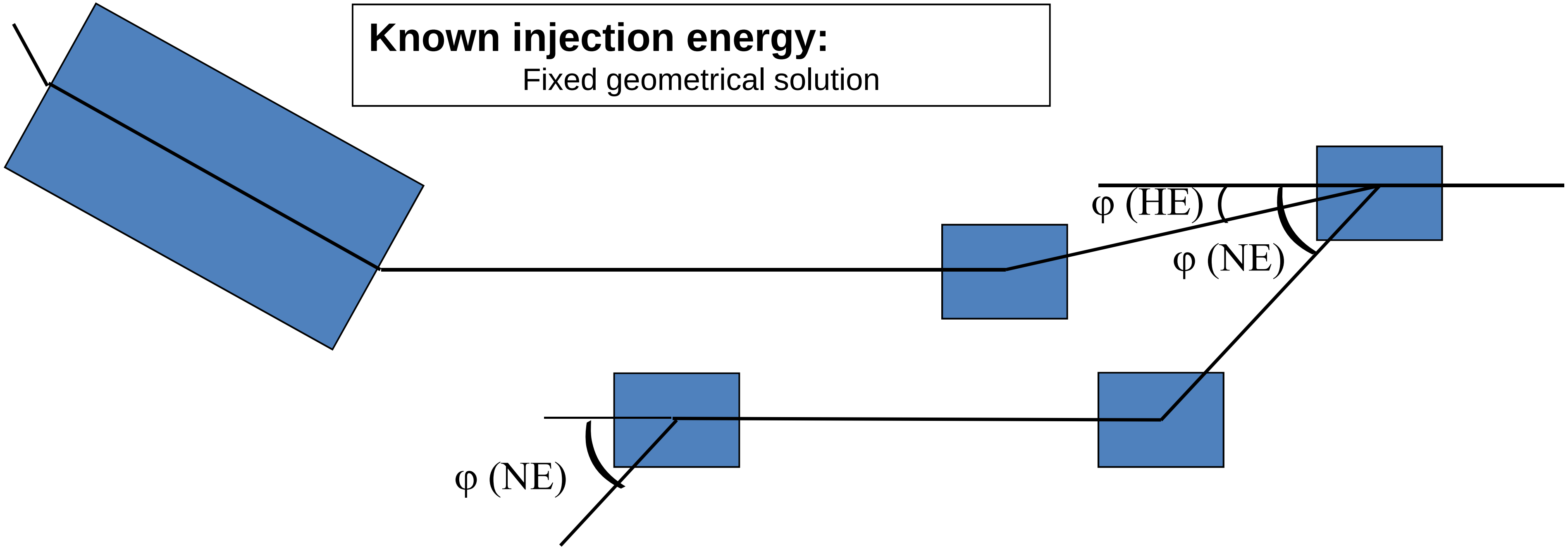
Variable injection energy:

$$\varphi(HE) / \psi(NE) = E_{inj} / E_{recirc}$$

MeV	NE [°]	HE [°]	Δx [cm]
3 / 50	15	0.9	-1.5
6.5 / 50	15	1.95	0
10 / 50	15	3	+1.5

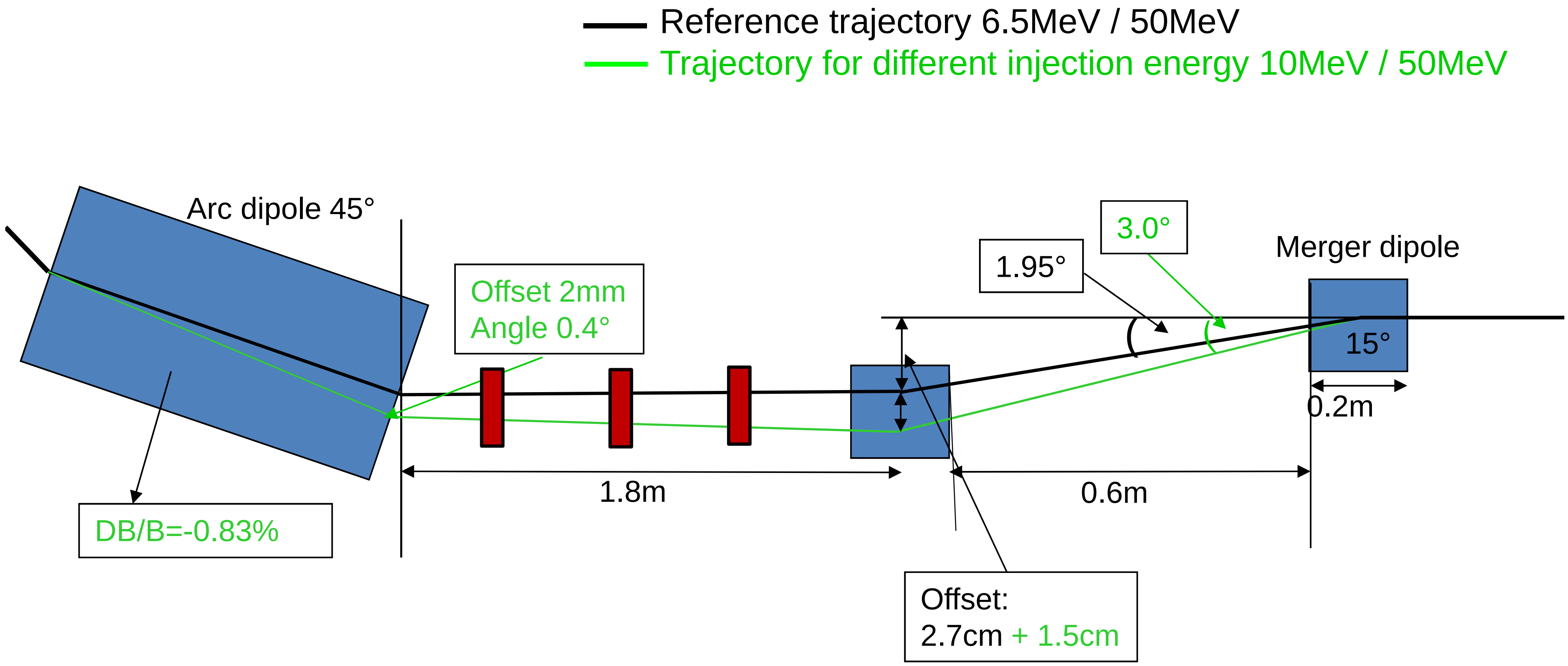


Known injection energy:
Fixed geometrical solution



- **How often do we vary the injection energy?**
  - **Probably not often / long procedure**
- **When will the injection energy be settled?**
  - **Probably before the linac is set up**
- **Is there a back up solution for later adoption of different injection energies?**
  - **Definitely, by including the arc dipole as a 3. steerer**

Estimate of Variations for an Injection Energy of 10MeV



- offsets in quadrupoles 0.5-1cm
- movable quadrupoles ?

Summary and Look out

- Adaption of optics to reduced project goal close to finalization
- No “show stoppers” identified
- Next steps:

  Merger decision

  Start to end calculations

  Tolerance studies
- CDR at the end of this year