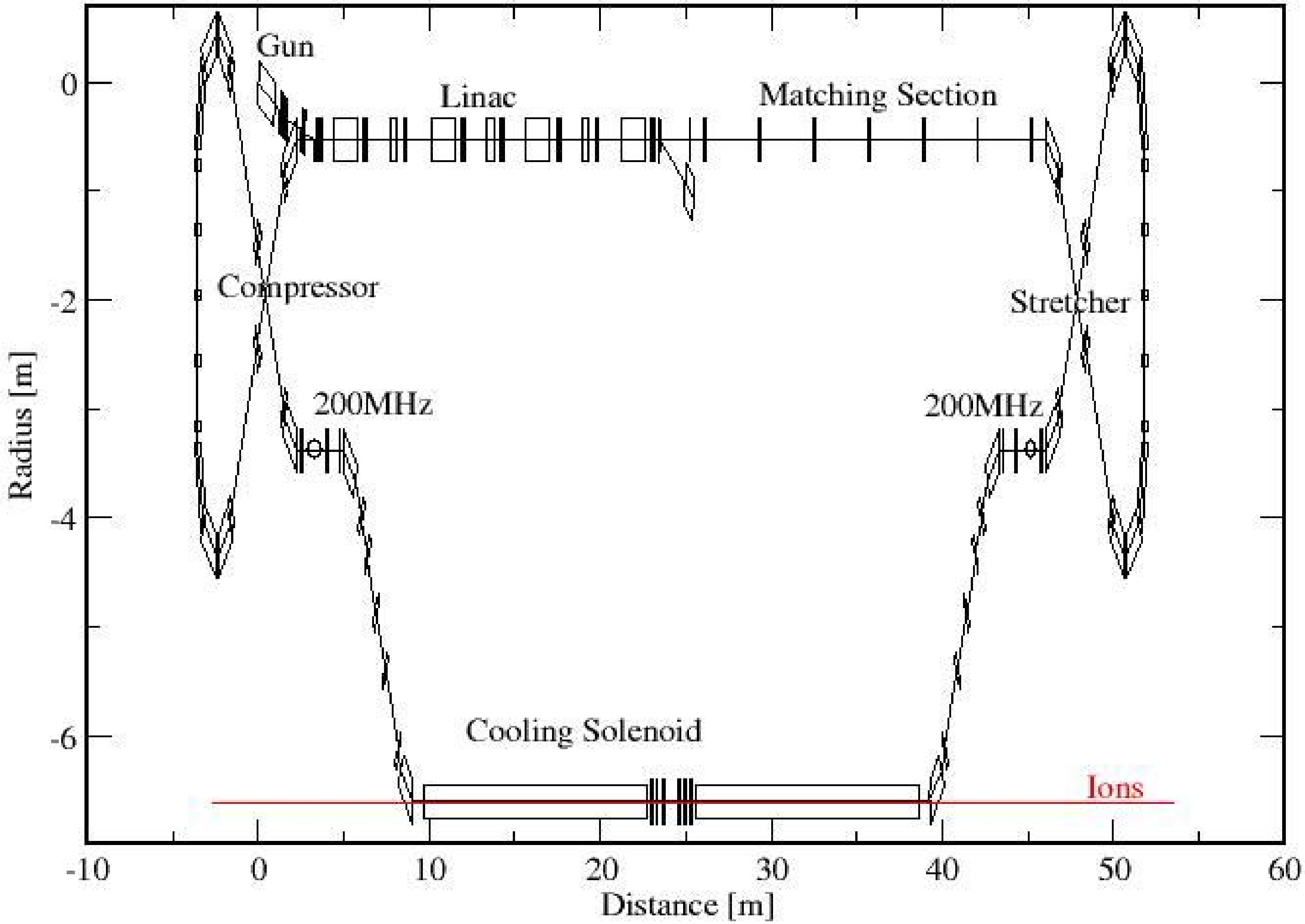
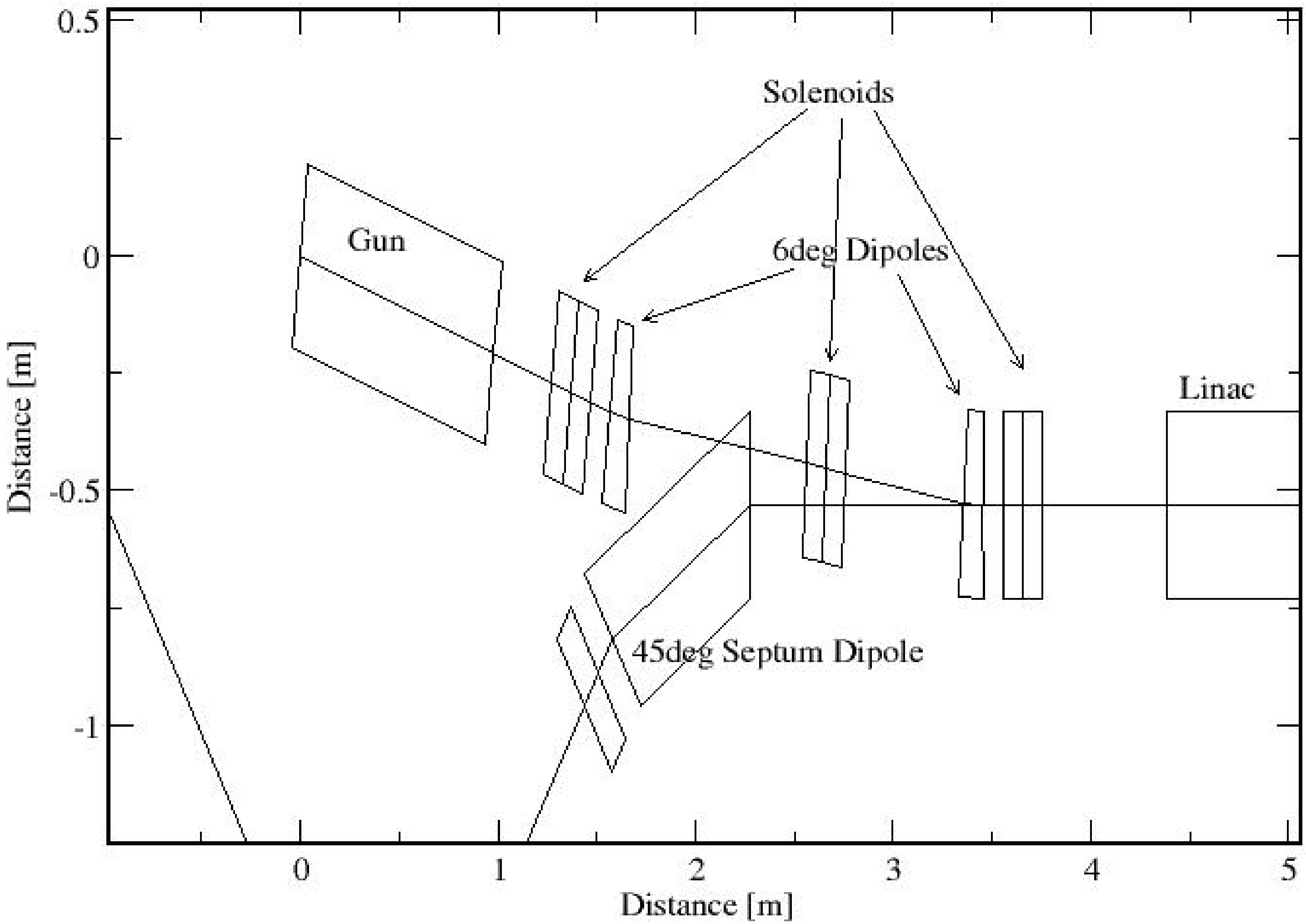
Beam Dynamics in the Electron Cooler

Jörg Kewisch

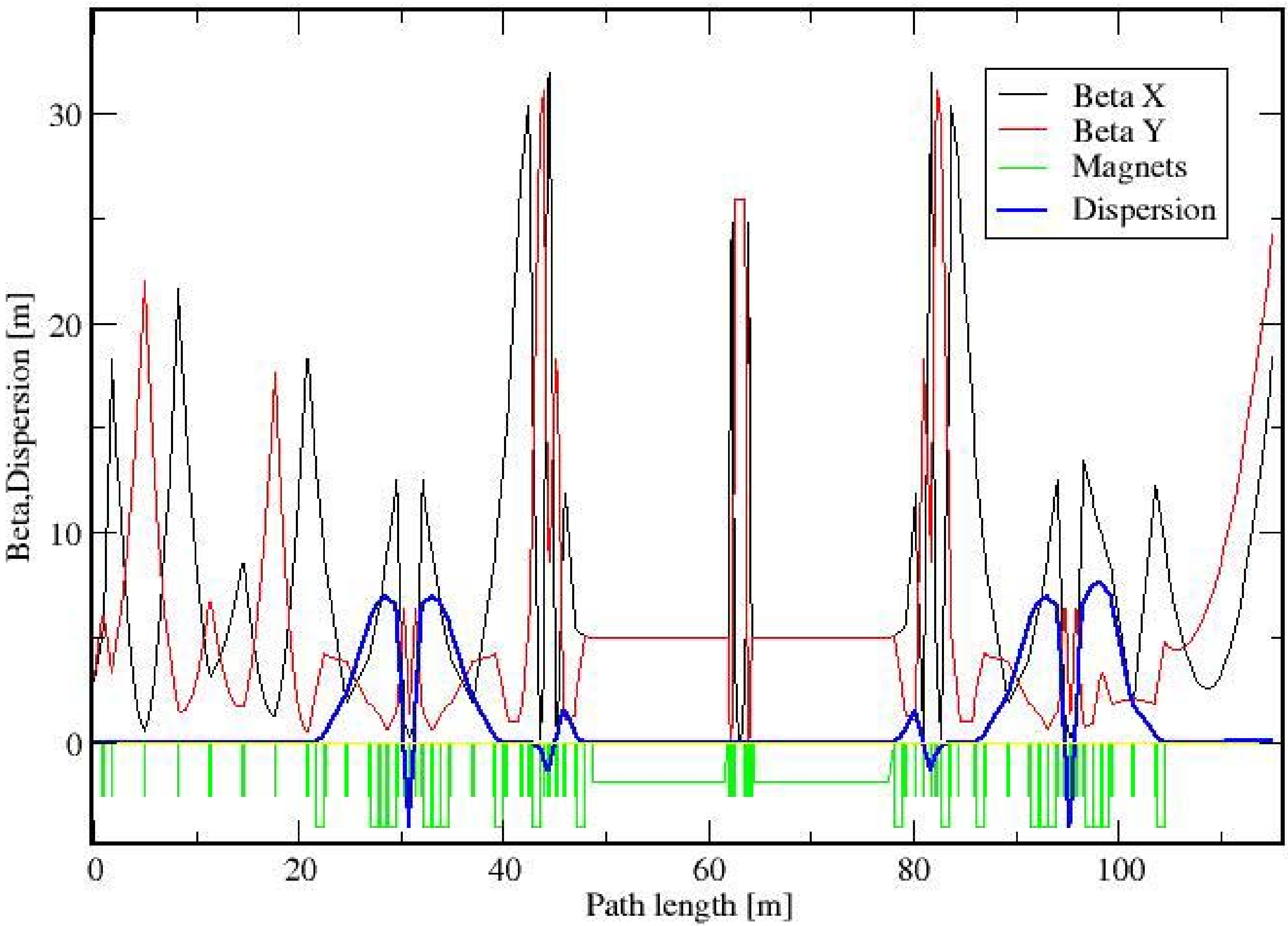
Cooler Layout



Cooler Layout



55 MeV Optics



Parameters

Cooling Section:

Energy:	55 Mev
Energy spread:	$1 \cdot 10^{-4}$
Bunch length:	15 cm
Bunch radius:	1mm
Emittance:	50 mm mrad
Solenoid:	1 Tesla

Linac:

700 MHz Cavities:	4
Gradient:	15 MV/m
2100 MHz Cavities:	3
Gradient:	7.5 MV/m
Power amplifiers:	50 kW

Arcs:

Max.Dispersion:	6 m
Max. Beam Size (rms):	5 cm
Stretch factor:	33 m

Gun:

Normal Conducting

700 MHz	2½ Cell
Bunch charge:	10 nC
Bunch frequency:	9.8 MHz
Beam Energy:	2.5 MeV
Power:	1MW

What is a "Magnetized Beam", Bush's Theorem

When a non-magnetized beam enters a solenoid, the fringe field increases the normalized emittance:

$$\varepsilon^2_{inside} = \varepsilon^2_{outside} + R^2\sigma^4\gamma^2 \quad \textbf{with} \quad R = \frac{1}{2}\frac{e}{pc}B_s$$

A magnetized beam rotates around the longitudinal axis (x ~ y′, y ~ -x′), so that the effect of the fringe field is canceled.

Busch's Theorem: If only axial symmetric fields are applied then:

$$r^2 \cdot \Theta' + r^2 \cdot \frac{e}{p} \cdot B = r_0^2 \cdot \frac{e}{p} \cdot B_0 \quad \textbf{with} \quad \Theta' = <\frac{y \cdot x' - x \cdot y'}{r^2}>, p = m_e\gamma\beta c$$

- A magnetized beam can only be made using a magnetic field on the cathode!
- The beam transport matrix from the cathode to the cooling section must be axial symmetric.
- Non-linearities disturb the balance.

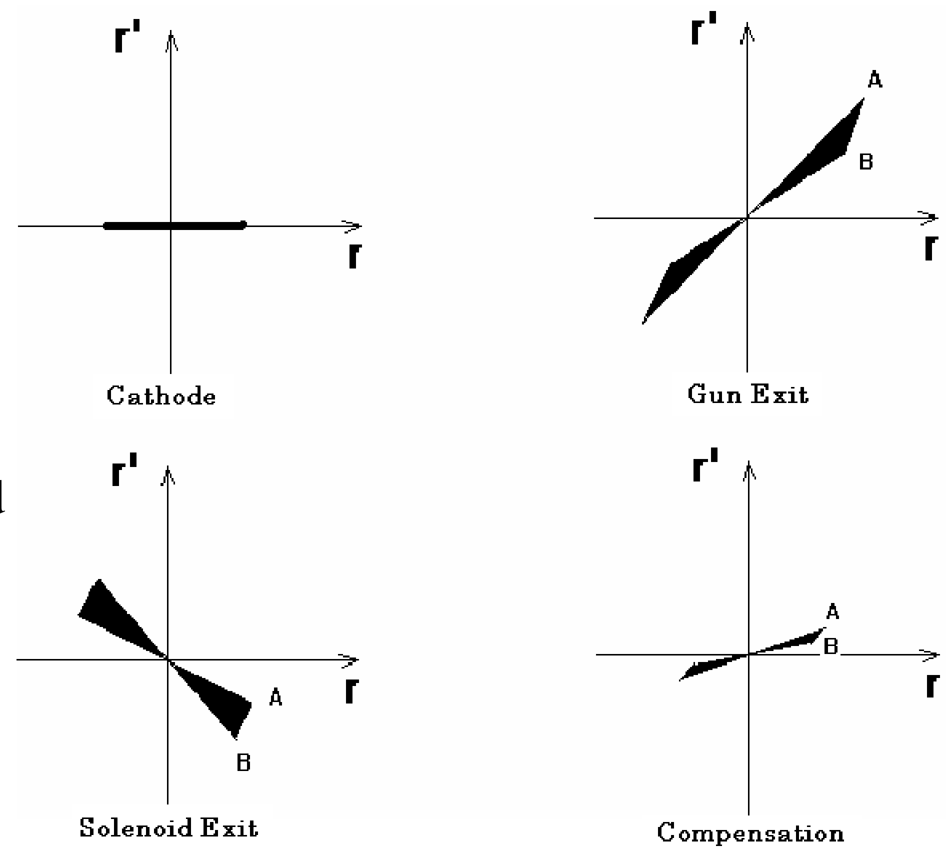
Traditional Emittance Compensation

•A bunch consists of longitudinal slices with small emittance.

•Slices experience different focusing from space charge and RF fields. The "over all" emittance increases.

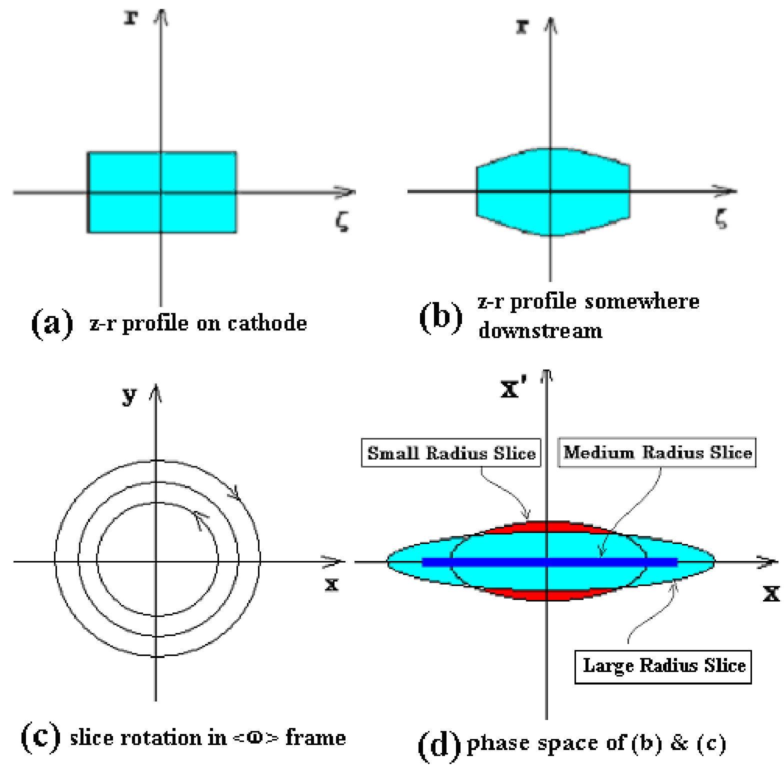
•Focusing with a solenoid and subsequent space charge defocusing reverses this effect.

•After minimum emittance is obtained the bunch is accelerated, space charge is no longer important.

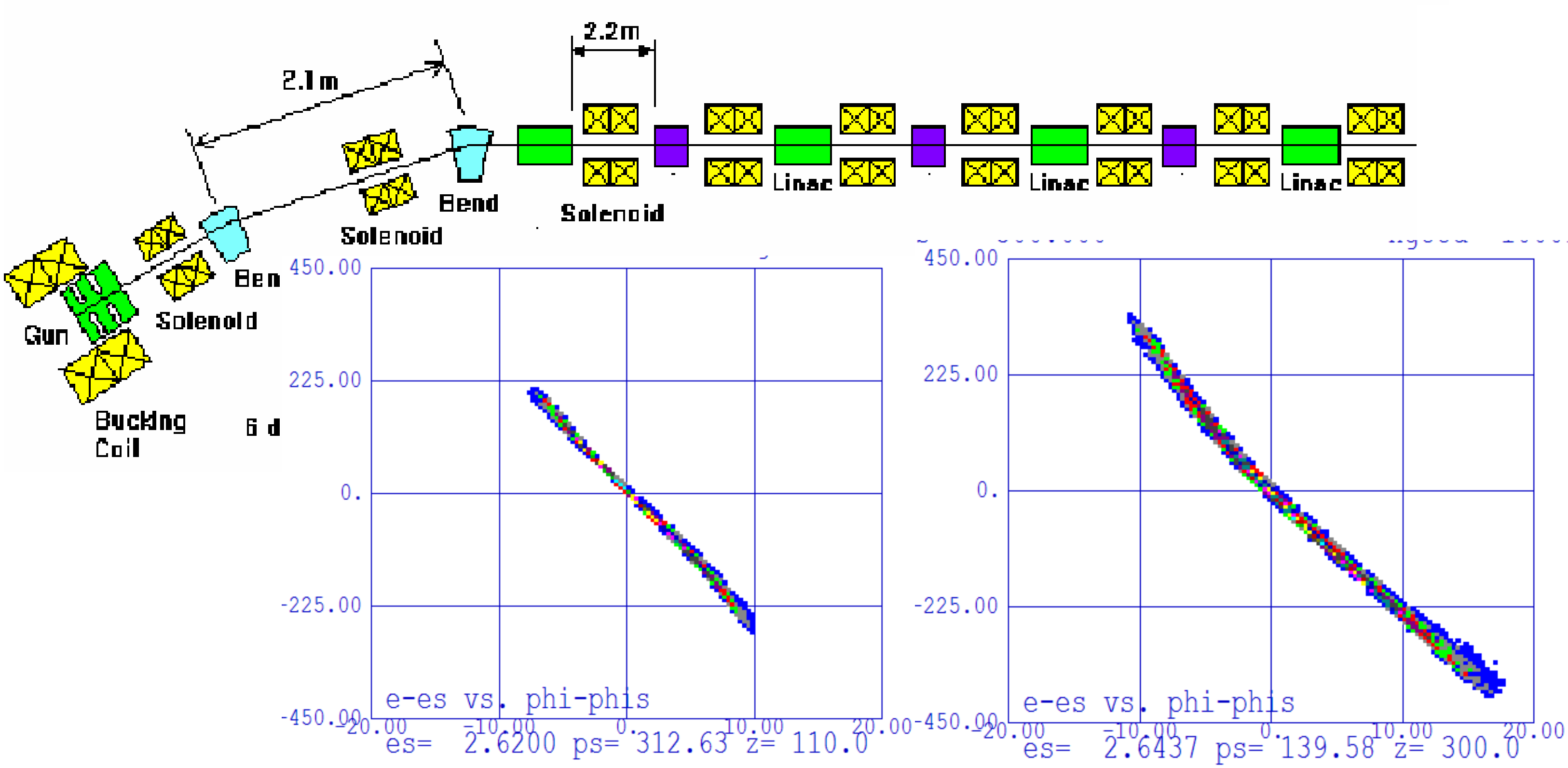


Magnetized Emittance Compensation

- For a magnetized beam a variation of radius causes strong emittance growth.
- Emittance compensation uses two focusing elements to keep radius and phase advance constant.
- The second focusing element is the fringe field of the accelerating cavity



Merge of Low Energy and High Energy Beam



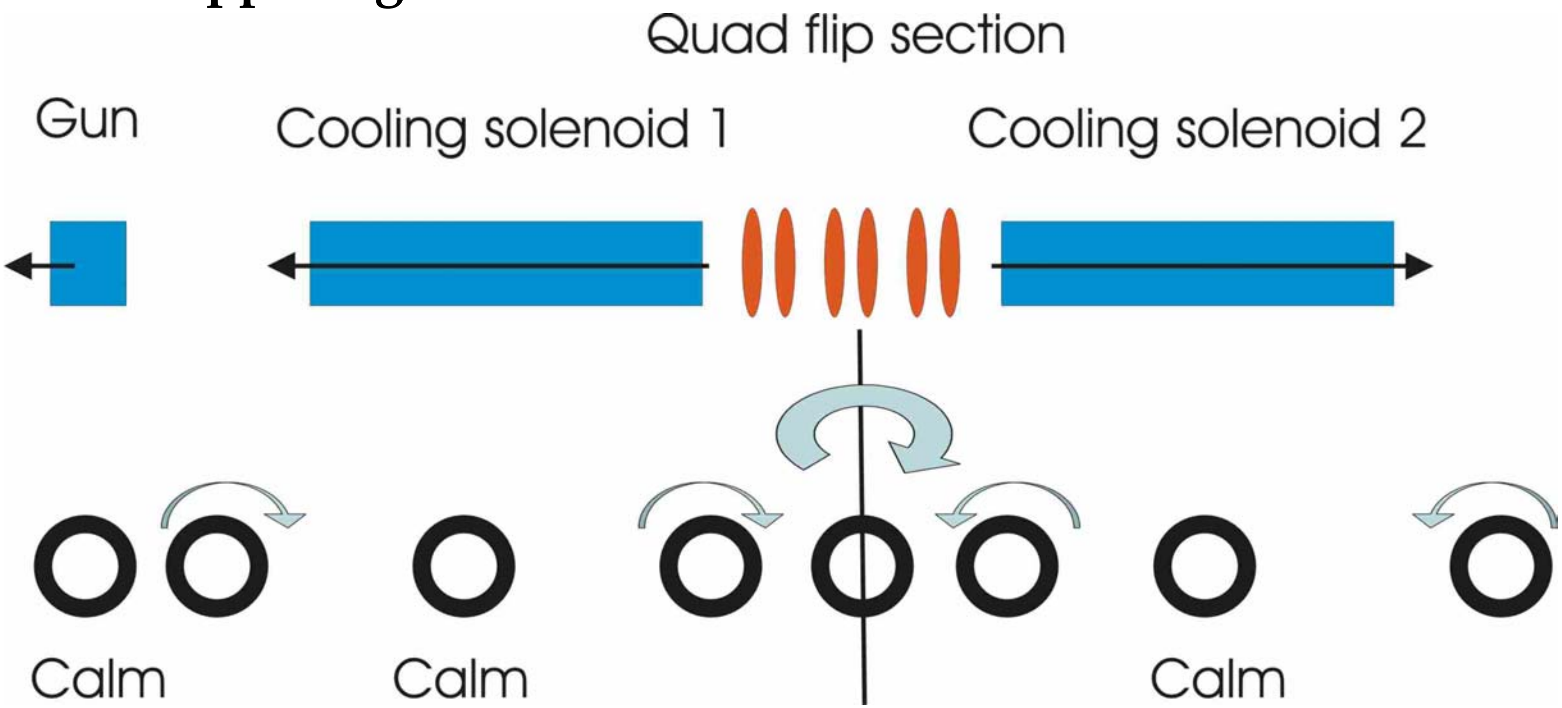
Longitudinal phase space at the first dipole and at second dipole

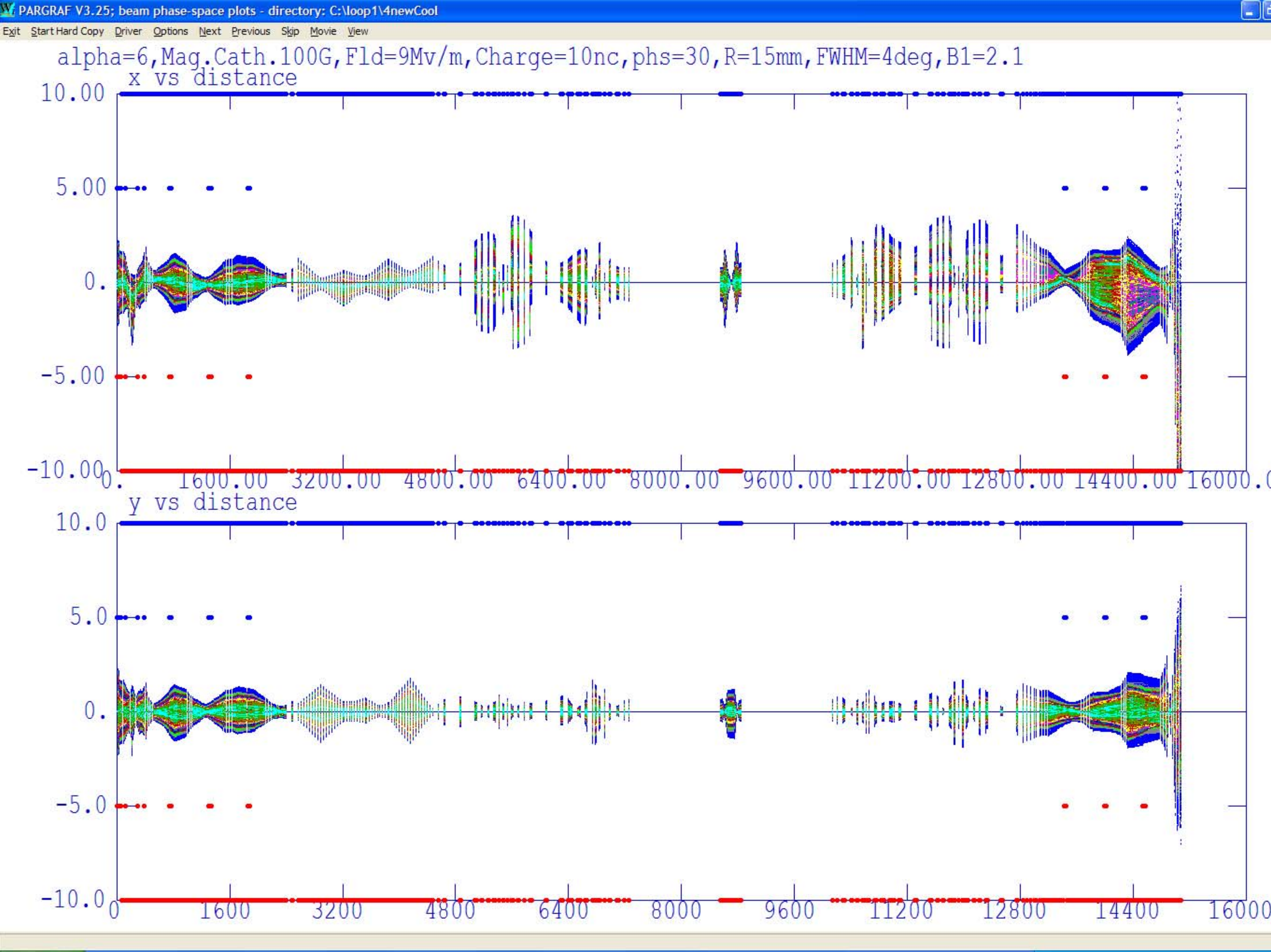
Stretcher/Compressor

- Energy spread reduced from $4 \cdot 10^{-4}$ to $1 \cdot 10^{-4}$ (rms)
- Energy spread $\frac{\Delta p}{p} = \pm 0.001$ introduced in the arc by mis-phasing last linac cavity.
- Arc provides $\Delta l = 33m \cdot \frac{\Delta p}{p}$, expands bunch length from 4.5 cm to 15 cm. Maximum dispersion is 6 m, maximum beam size 5 cm.
- 200 MHz normal conducting RHIC cavity used to remove energy spread.
- Second 200 MHz cavity introduces opposite energy spread
- Second arc shortens bunch length for energy recovery.

Solenoid Gap

- For technical reasons the cooling solenoid will be split into two sections. Extra focusing is necessary to maintain magnetization.
- We will use quadrupoles to obtain 180°/360° phase advance. This allows opposing field direction in the solenoid halfs.




PARGRAF V3.25; beam phase-space plots - directory: C:\loop1\4newCool
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x vs distance
10.00
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-5.00
-10.00
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1600.00
3200.00
4800.00
6400.00
8000.00
9600.00
11200.00
12800.00
14400.00
y vs distance
10.0
5.0
0.
-5.0
-10.0
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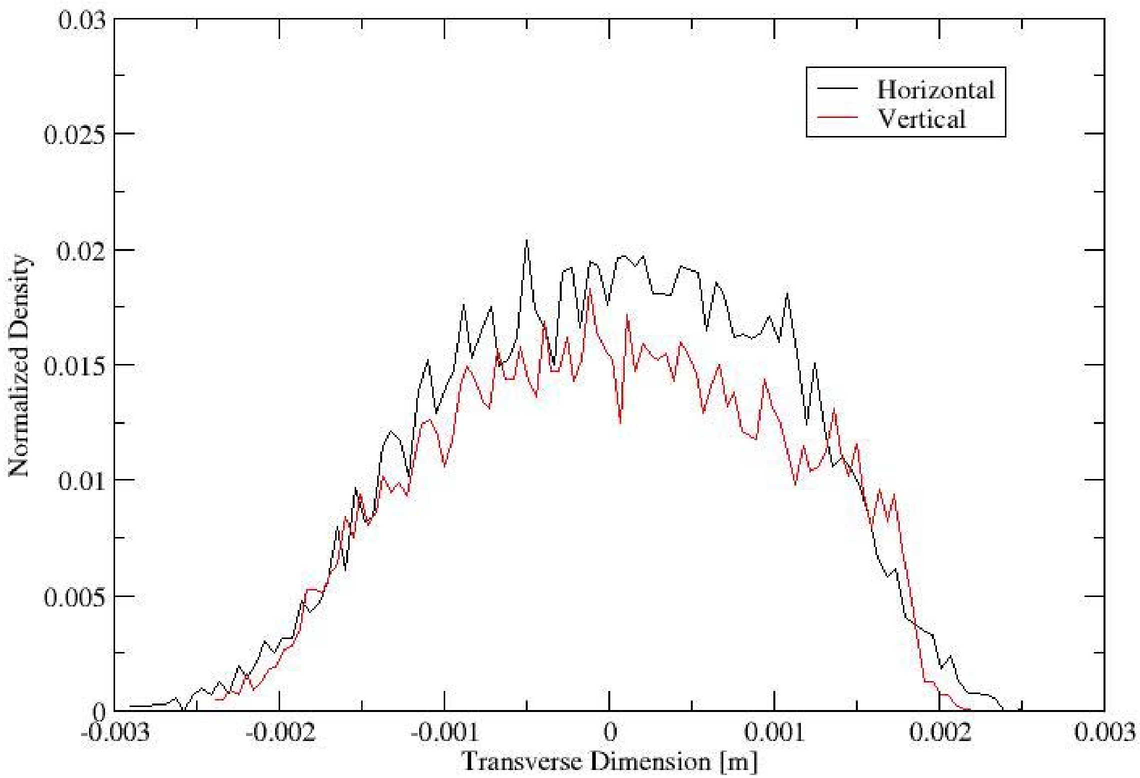
1600
3200
4800
6400
8000
9600
11200
12800
14400
16000

Profiles in the Cooler Solenoid



Front to End Simulation: Emittance

$$T_{\perp}[eV] = m_e c^2 \cdot \frac{\varepsilon_n^2}{\sigma^2} = 0.511 * (\varepsilon_n [mm \cdot mrad])^2$$

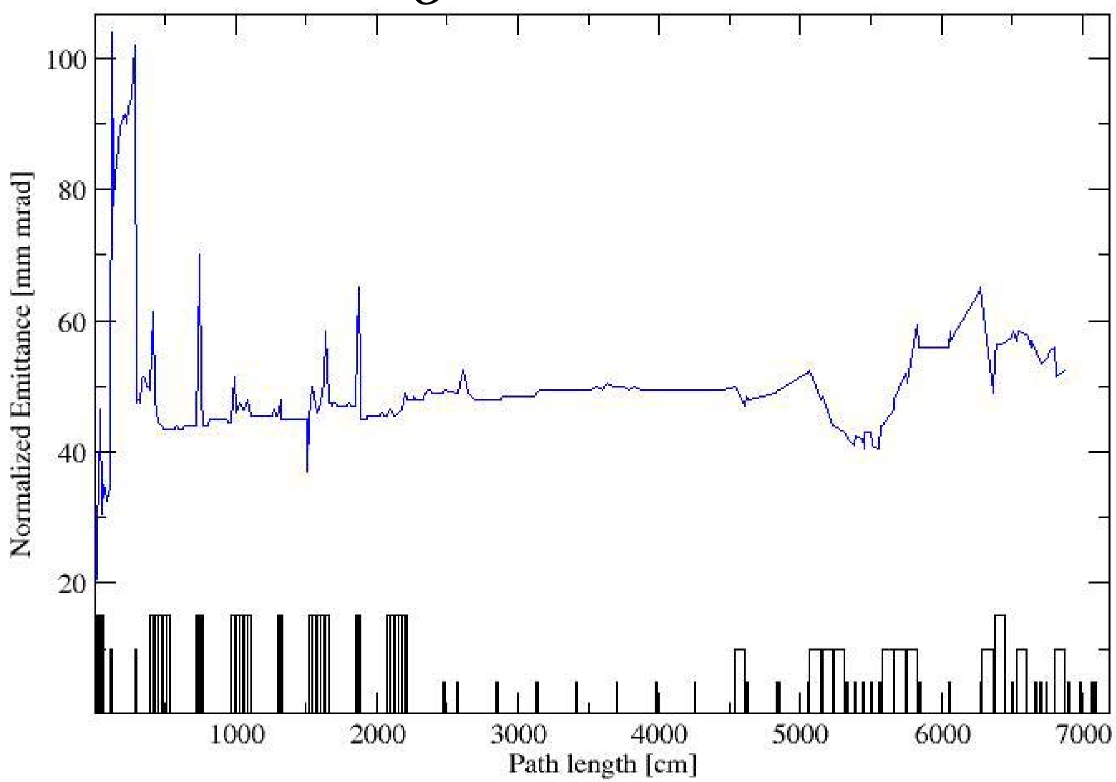
Method:

•Track electrons using PARMELA including space charge

•Apply linear transformation to make transport axial symmetric, remove dispersion

•Apply solenoid fringe field matrix

•Measure emittance



To Do

- **Tolerances: Alignment errors, non-linear field components.**
- **Instrumentation: Position, profile, energy, recombination.**
- **Correctors**
- **Commissioning plan.**
- **Further optimization of emittance.**
  - Focusing
  - "Constant Density Elliptical Shape" distribution
  - Bunching Cavity

Work in Progress

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RHIC