The **A**nti-**B**end **C**ell for low emittance

up to factor 2 lower emittance

without J_x-manipulation

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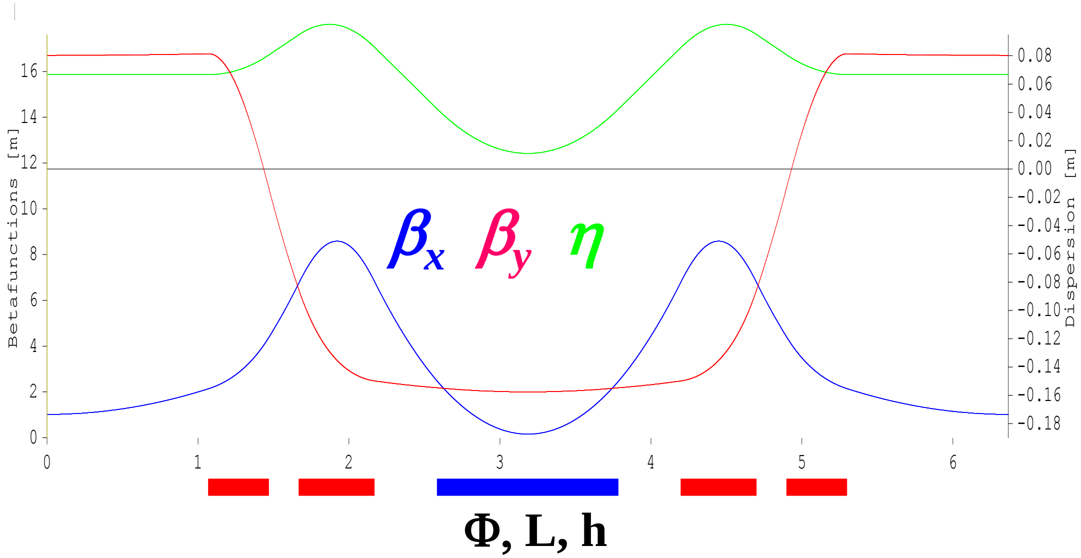
Classical TME cell

Theoretical Minimum Emittance: $\epsilon_{xo}[\text{pm rad}] = \frac{7.8}{J_x}(E[\text{GeV}])^2(\Phi[^\circ])^3 \frac{F}{12\sqrt{15}}$,



$$F^{\min} = 1$$

$$\beta_{xo}^{\min} = \frac{1}{2\sqrt{15}}L \qquad \eta_o^{\min} = \frac{hL^2}{24}$$

$$h = 1/\rho$$

Problem

Get minimum β_o, η_o at center and periodic solution ($\alpha = \eta' = 0$ at ends)

→ cell phase advance: $\mu = 284.5°$

→ long cell, strong quads, large chroma... ✘

Deviations from minimum conditions

$$F = \varepsilon / \varepsilon^{\min}$$

$$b = \frac{\beta_{xo}}{\beta_{xo}^{\min}}$$

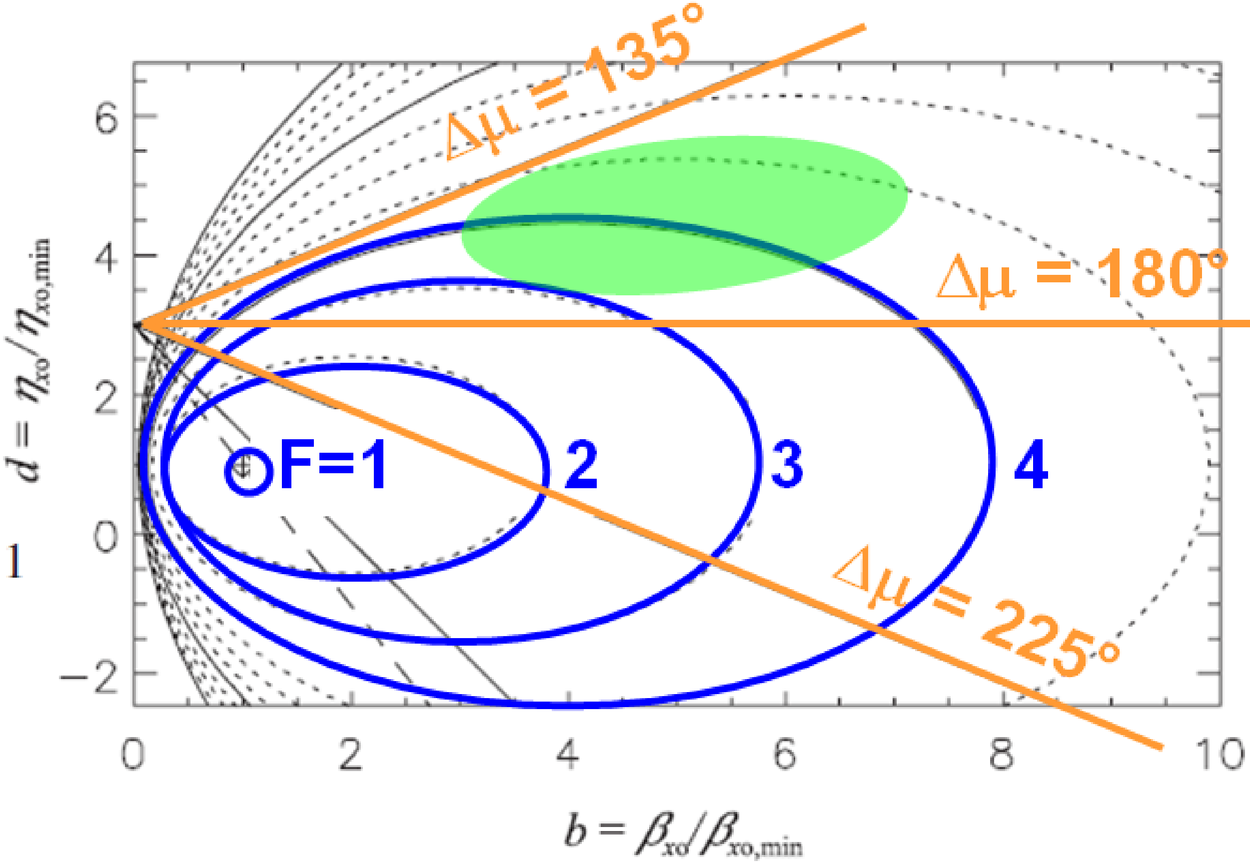
$$d = \eta_o / \eta_o^{\min}$$

Ellipse equation:

$$\frac{5}{4}(d-1)^2 + (b-F)^2 = F^2 - 1$$

Cell phase advance

$$\tan\frac{\mu}{2} = \frac{6}{\sqrt{15}} \frac{b}{(d-3)}$$



→ real cells: $\Delta\mu < 180°$ → $F \sim 3...6$

The anti-bend cell concept

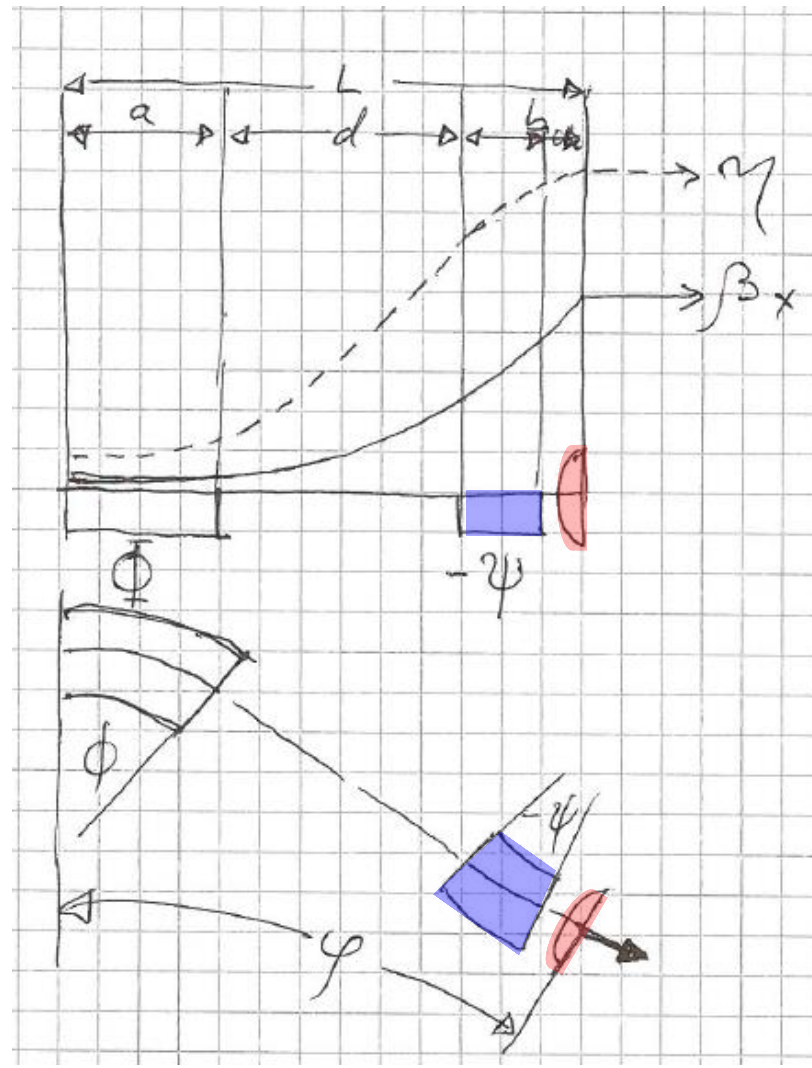
- TME cell: too weak focusing of dispersion

→ add a small negative dipole: **anti-bend**
$\Delta\eta' = \sin\,\psi \qquad \psi < 0$

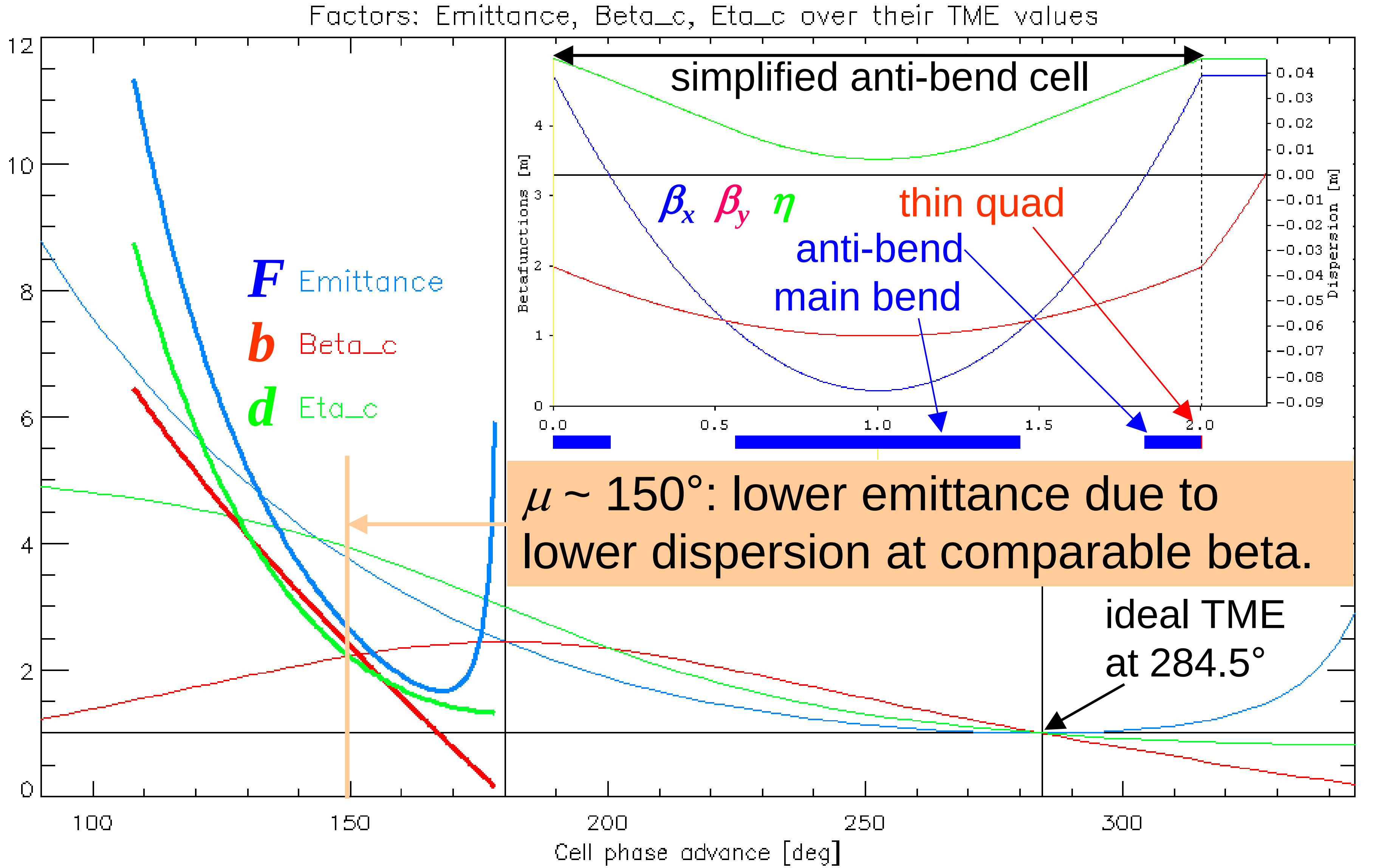
- quads only for beta-matching at moderate phase advance μ.

→ TME optics at lower μ !

- Side effects on emittance:
  – main dipole angle increased by $|\psi|$
  – anti-bend at large $\mathcal{H}$



Anti-bend vs. TME cell



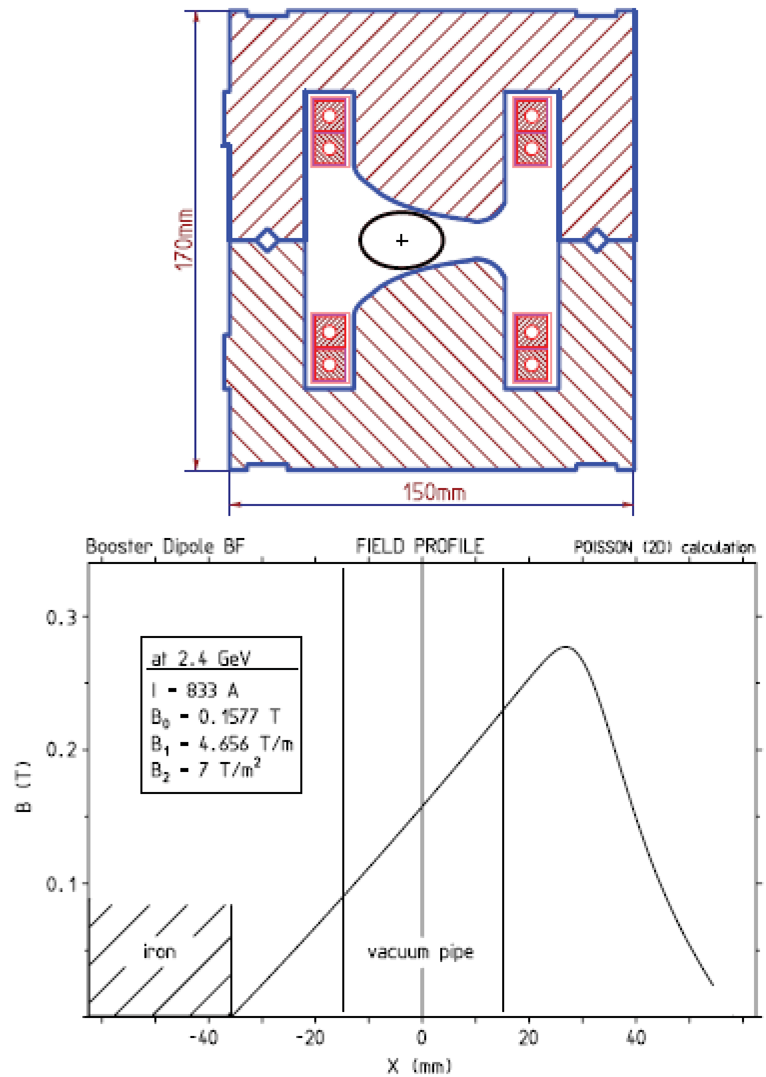
thick lines: anti-bend

thin lines: TME

J_x adjustment

$$J_x = 1 - \frac{\oint h\eta(h^2 + 2b_2)\,ds}{\oint h^2 ds}$$

h = dipole curvature = $1/\rho$



SLS booster half quad

- push J_x ⇨ ~2 to get half emittance ($\varepsilon \sim 1/J_x$)
- $\eta > 0$ $h > 0$ $b_2 < 0$ defocusing gradient bend
- $\eta > 0$ $h < 0$ $b_2 > 0$ focusing gradient anti-bend
- convenient magnet design: anti-bend = half quadrupole

Example

6.43° cell

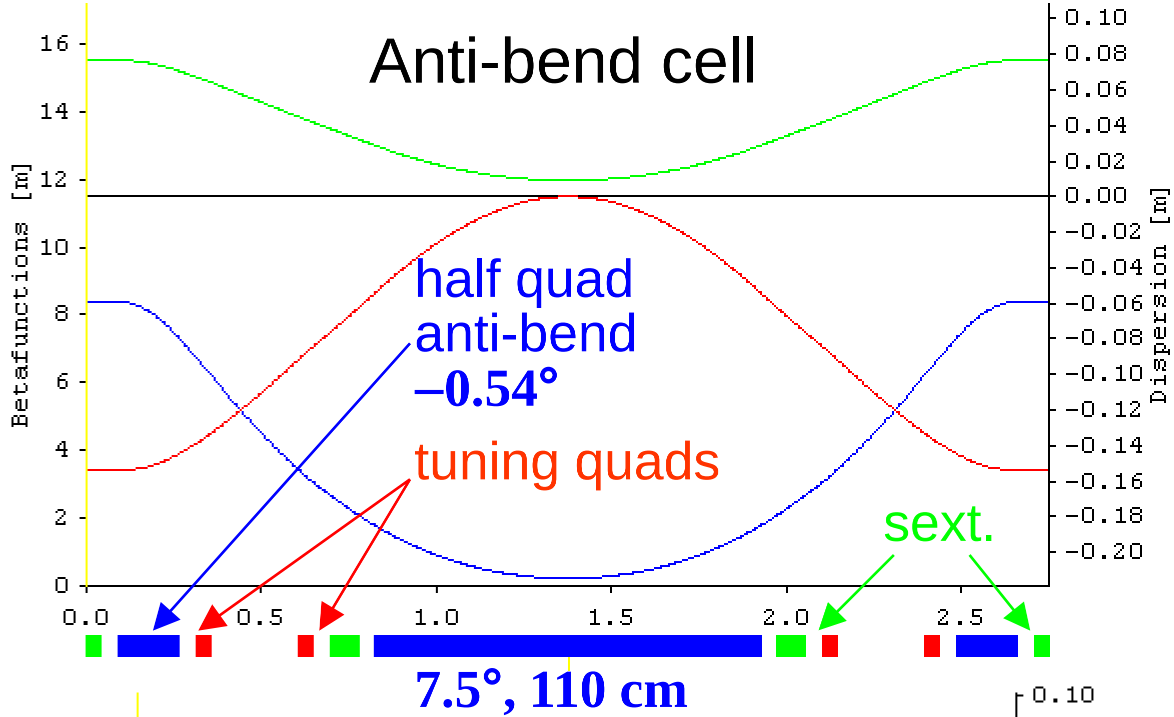
2.4 GeV

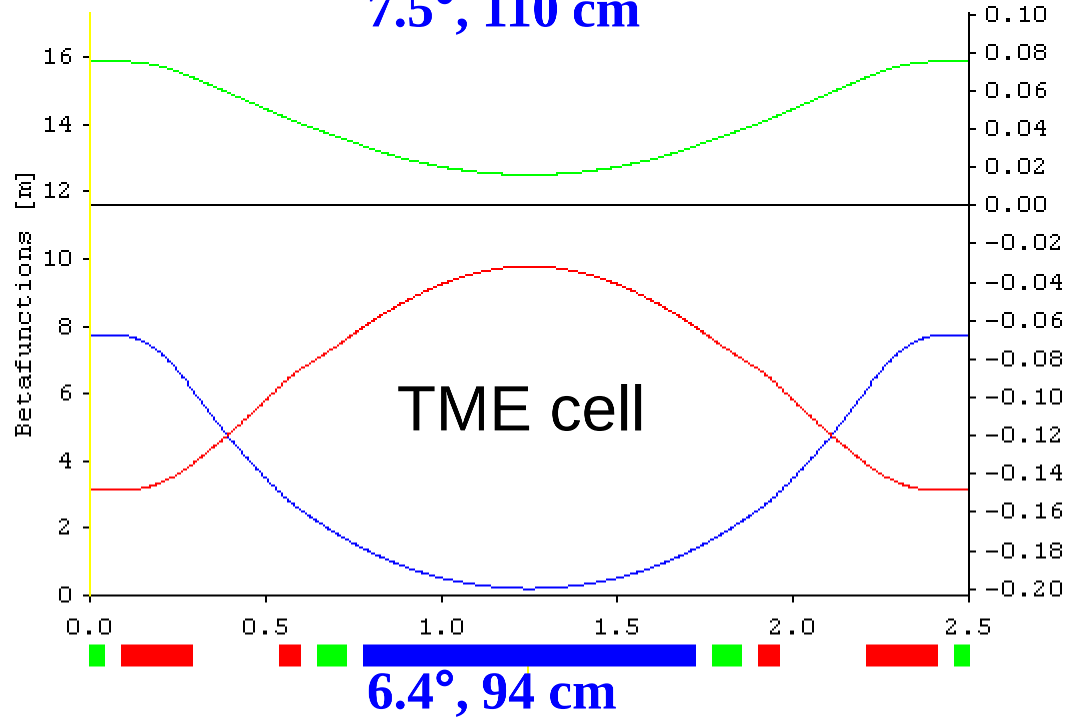
$\mu_x = 154.2°$ (= 3 / 7)

$\mu_y = 25.7°$ (= 1 / 14)

Comparison

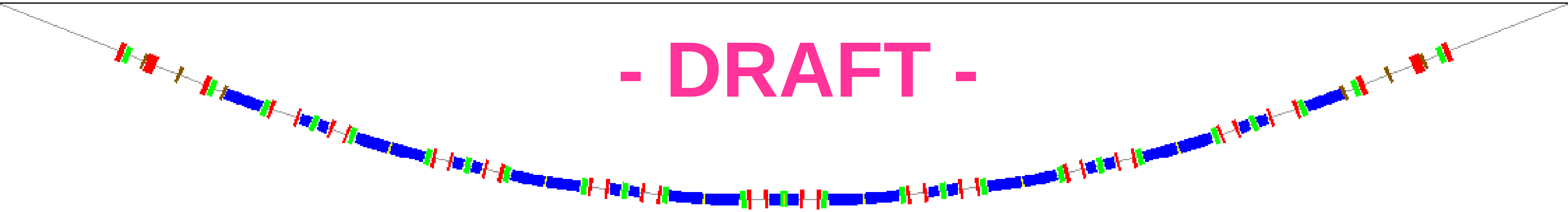
	ABC	TME
ε	**258**	**739 pm**
J_x	1.97	1.32
$\varepsilon \cdot J_x$	**508**	**975 pm**
L	2.75	2.50 m
σ_e	9.7	7.7 $\times 10^{-4}$
ΔE	7.7	6.3 keV

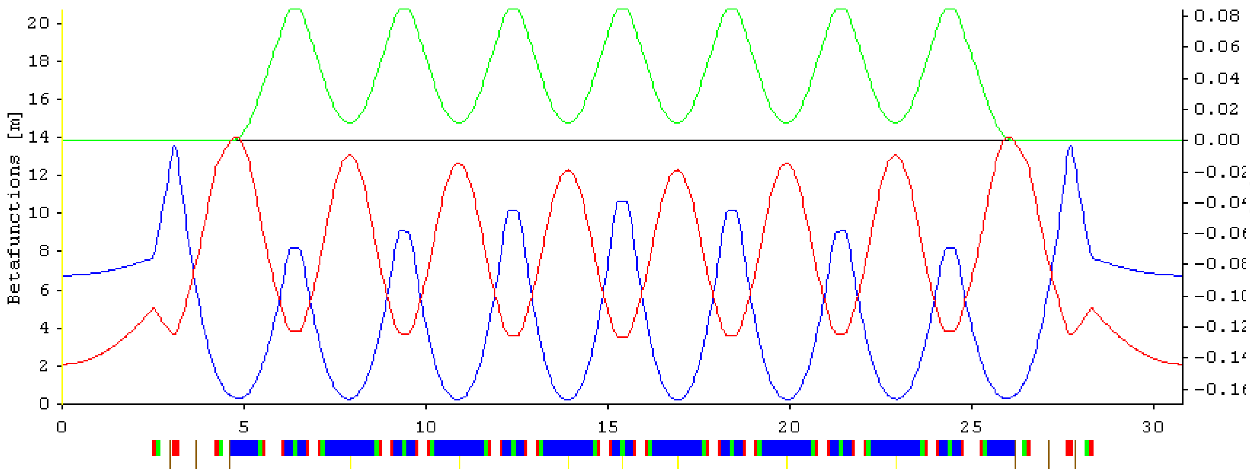


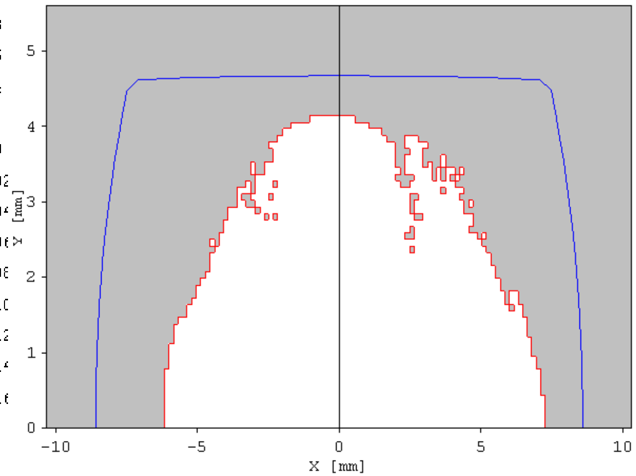


Compact low-emittance ring

- DRAFT -







DA and 24 mm ∅ beam pipe

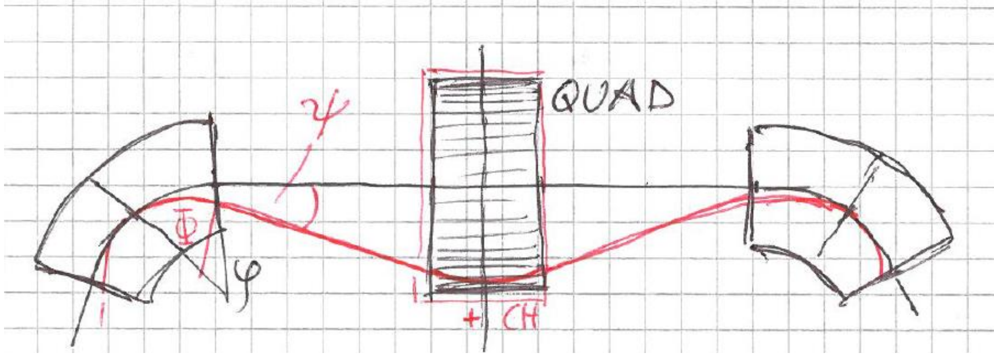
- 8 × 45° 8BA (7 cells), 8 × 5 m straights.
- **2.4 GeV**, **246 m** circumference.
- **ε = 228 pm**, $J_x = 2.24$, $\sigma_e = 0.107$ %, $\Delta E = 367$ keV.
- $B_{poletip}$ (T) for R=15 mm: bends 1.0, quads 0.8, sext 0.5, oct 0.1

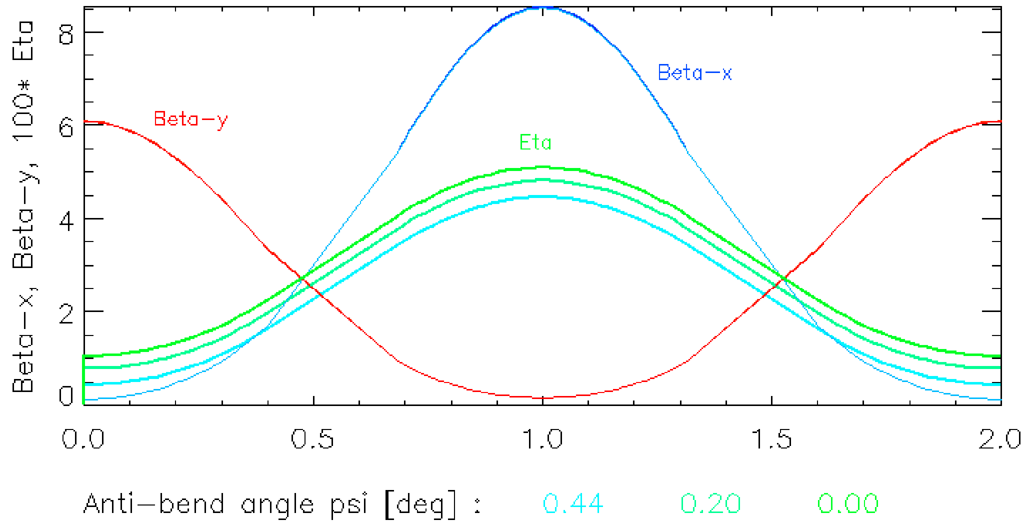
Orbit bump

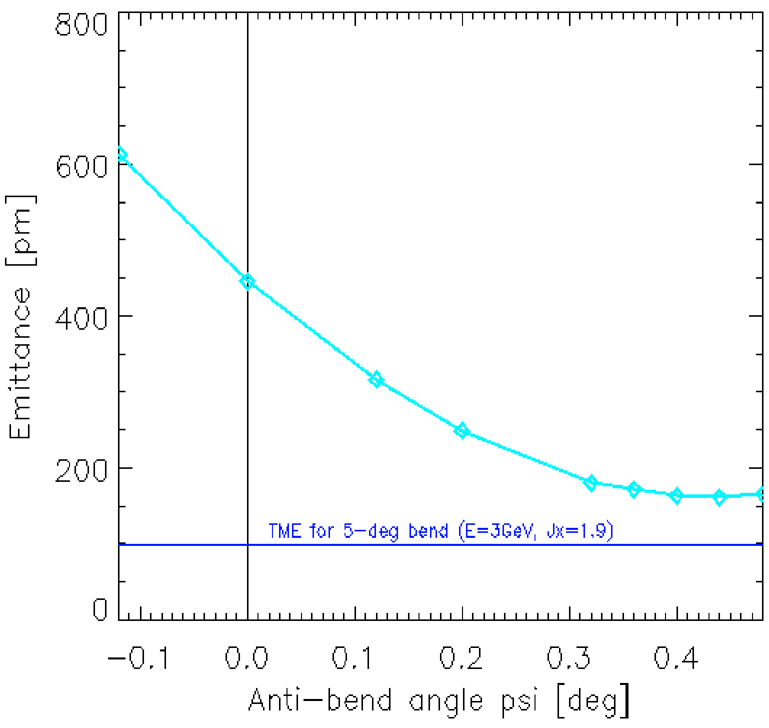
Anti-bend from dipole downfeed in quadrupole.

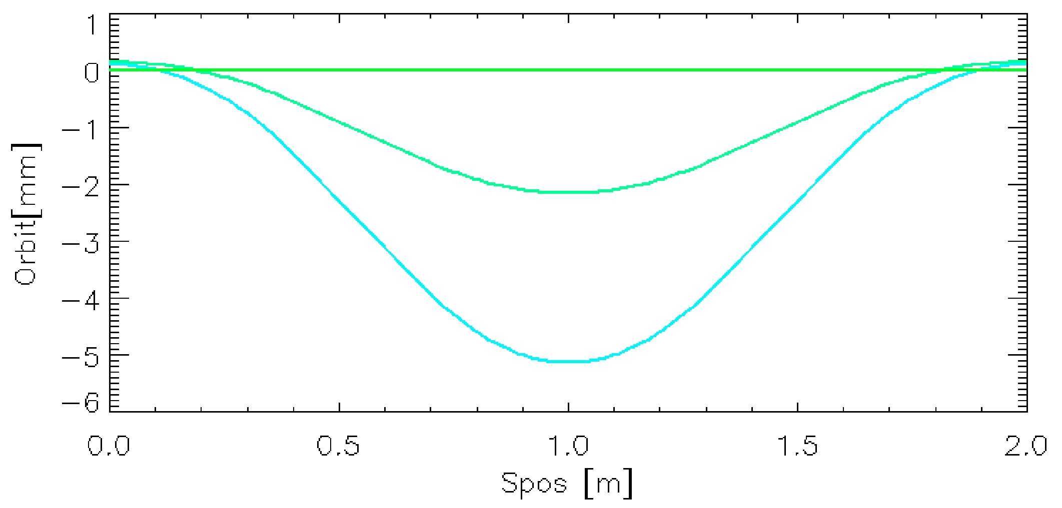
(TRACY simulation)

known from $\Delta p < 0$ orbits !









Conclusion

- A small anti-bend provides the dispersion matching missing in the standard TME cell.
- Almost factor 2 lower emittance compared to TME cell of same tune and same J_x.
- Disadvantage: requires rather high cell tune ~ 0.42..0.44 (150..160°).
- Anti-bend as half quad: set J_x ~ 2, and convenient magnet design.