Beam crossing and performance for upgrade optics' with $\beta^* = 0.25$ m

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Collision optics'

- **Three optics' (Riccardo):**
  - **Compact optics**
  - **Modular optics**
  - **Small** β_{max}
- **Can we make the crossing scheme ?**
- **Possible performance (luminosity)**

Historical note:

- **LHC parameters in February 1989 (3 experiments):**
  - $\beta^* = 0.25$ **m, bunch spacing 15 ns (but E = 8 TeV)**
- **Abandoned because:**
  - **Necessary crossing angle large and difficult to make (aperture)**
  - **Strong geometric reduction of luminosity**
  - **Moved to** $\beta^* = 0.50$ **m, bunch spacing 25 ns**
  - **Normalized separation** $\approx 7\ \sigma$
  - **But: no correct crossing scheme available for tracking**
- **After detailed studies present scheme with** $\approx 10\ \sigma$

For crossing schemes:

- **Boundary conditions:**
  - **Minimum separation in drift space: 10 σ**
  - **No aperture limit considered in triplet or D1**
  - **Keep possible strength in orbit correctors, requires the use of MCBX**
  - **Assume no early separation scheme**
  - **Assume nominal parameters (ϵ^*, σ_s ...)**
- **Avoid too large effective crossing angle, if possible**

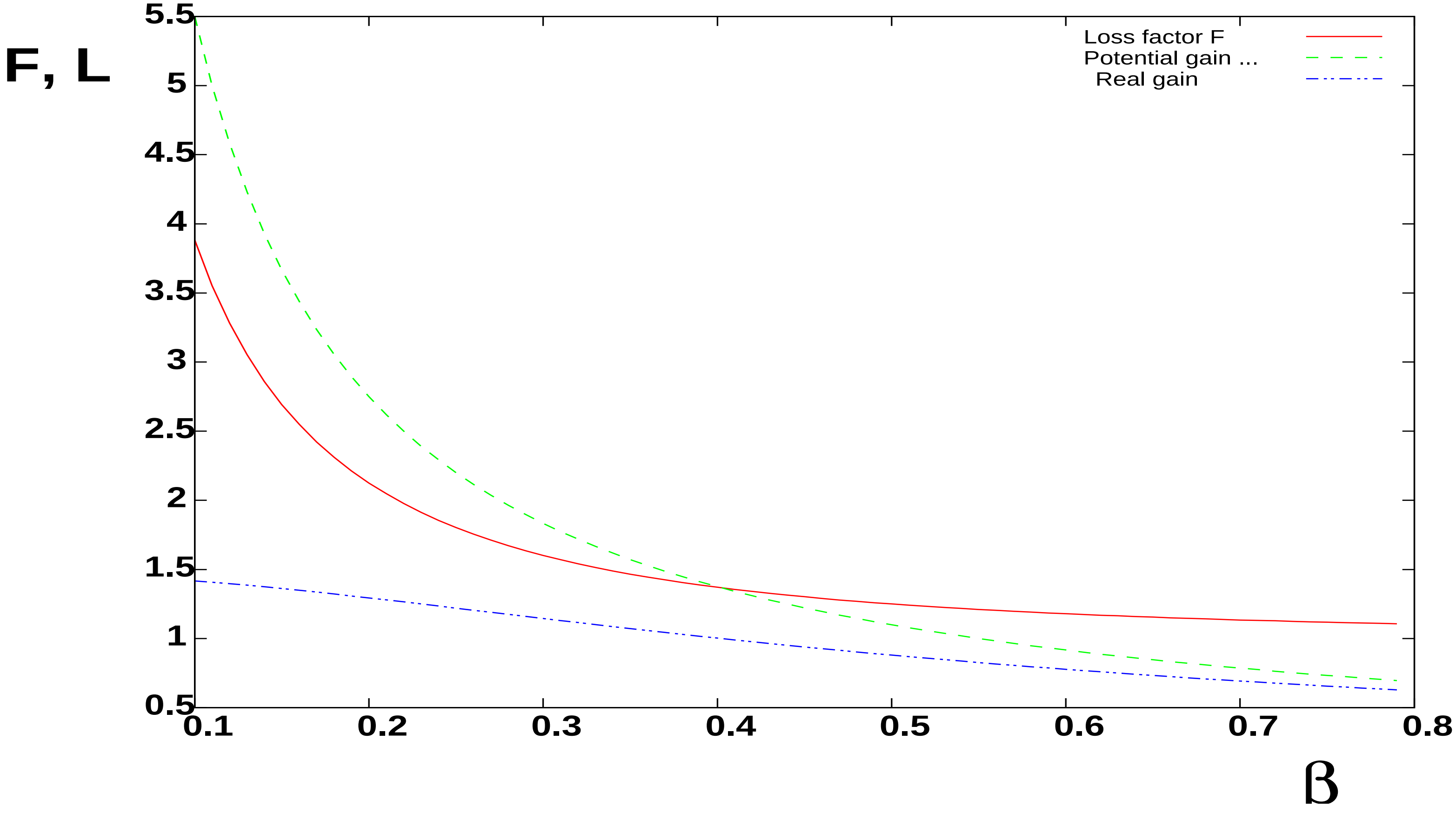
Reminder:

$$d_{sep}^{drift} \approx \frac{\alpha \;\cdot\; \sqrt{\beta^*}}{\sqrt{\epsilon}}$$

$$\frac{\mathcal{L}(\alpha = 0)}{\mathcal{L}(\alpha)} = F \approx \sqrt{1 + (\frac{\alpha \sigma_s}{2\sigma_c})^2} = \sqrt{1 + (\frac{\alpha \sigma_s}{2\epsilon\beta^*})^2}$$

- **To small α: not enough separation**
- **To large α: little (or no) luminosity gain**
- **LHC: ($\alpha \approx$ 142.5 μrad, $\beta^* \approx$ 0.55 m): F $\approx$ 1.20**

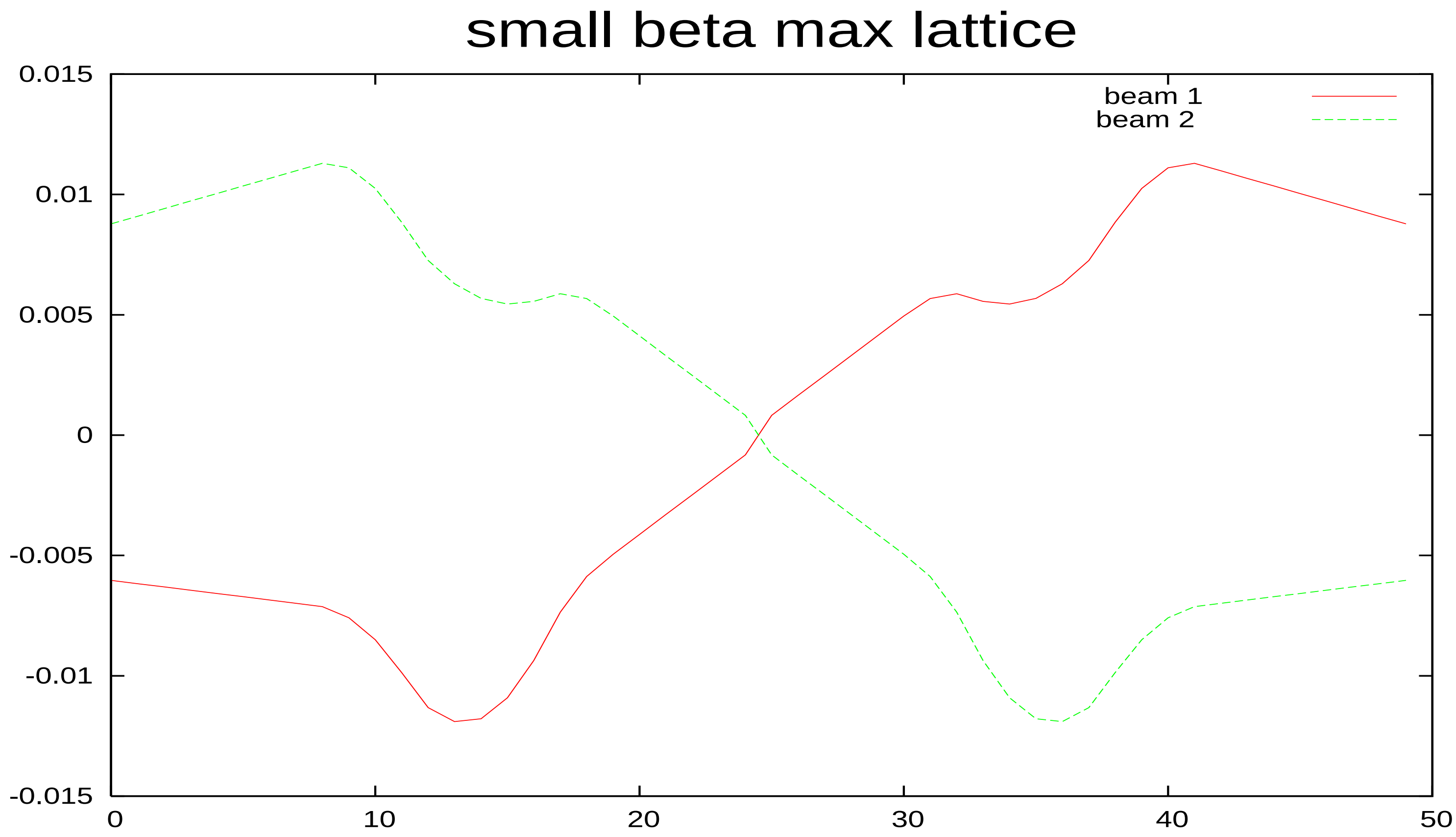
Geometrical loss for constant separation



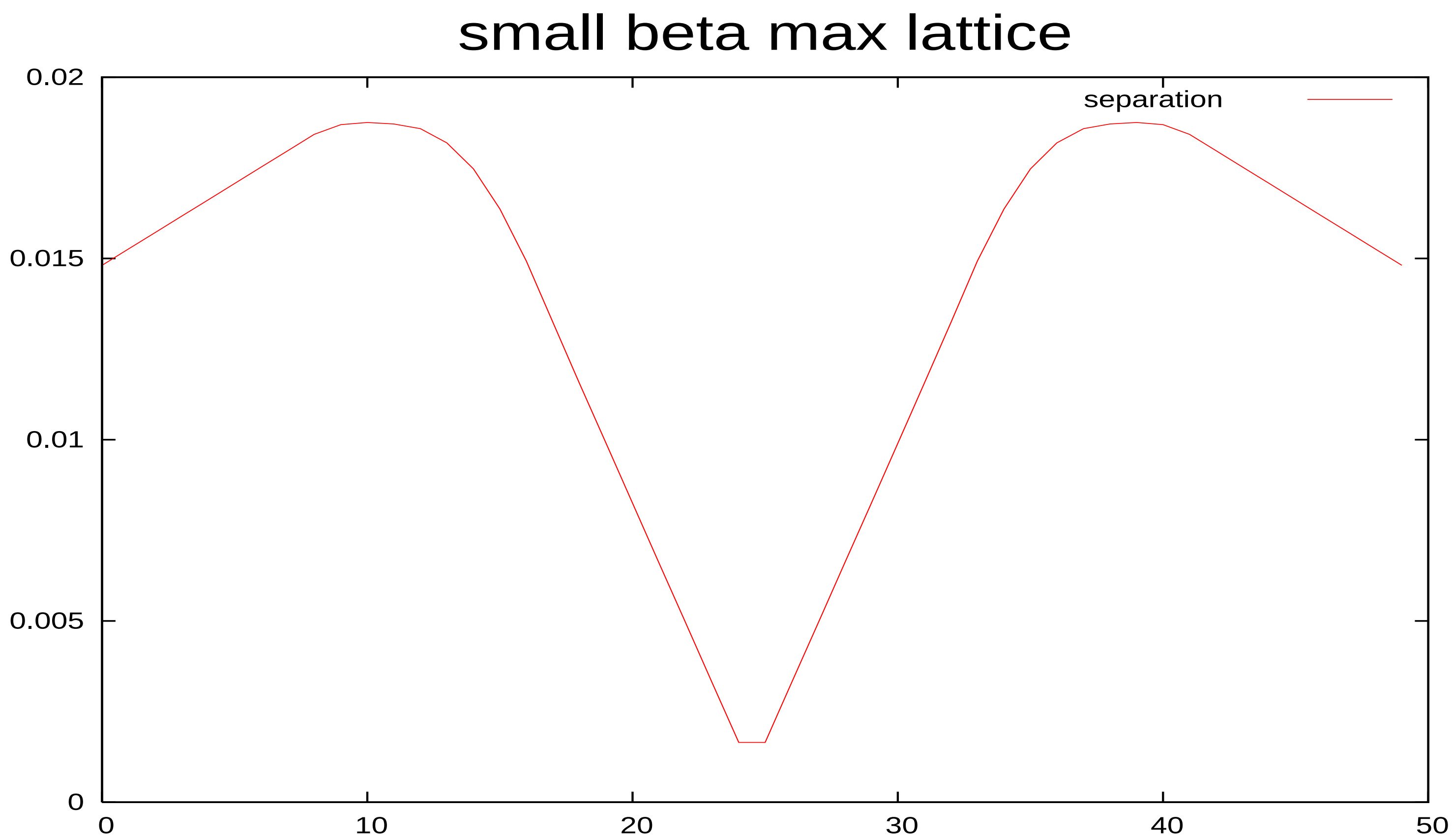
Long range interactions

- **Parasitic encounters $\rightarrow$**
- **For compact and small β_{max} assume same as nominal**
- **For modular lattice:**
  - **Distance between IP and D1 larger**
  - **More parasitic interactions ($\approx$ 50)**

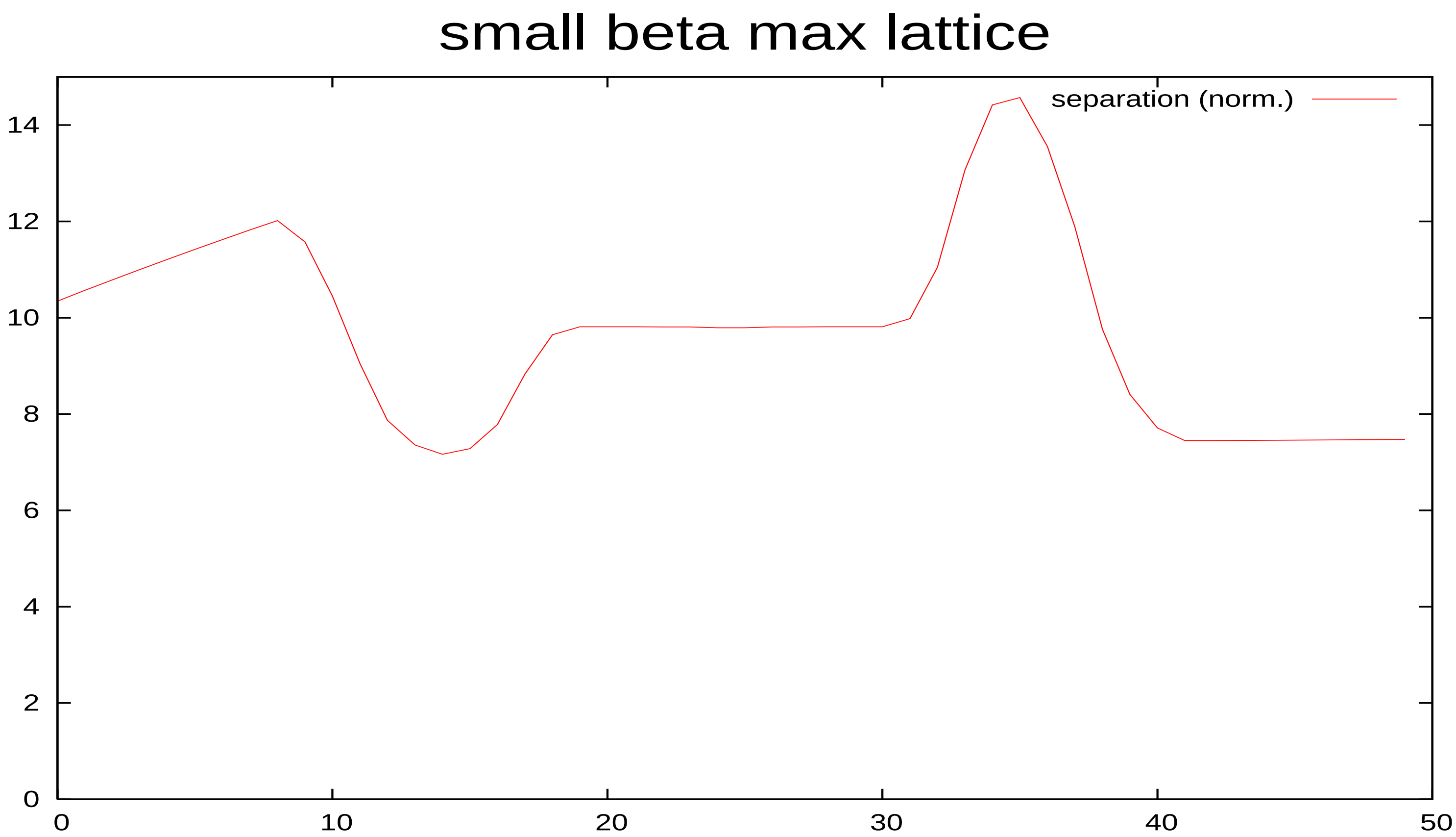
Collision scheme - orbits



Collision scheme - separation



Collision scheme - normalized separation



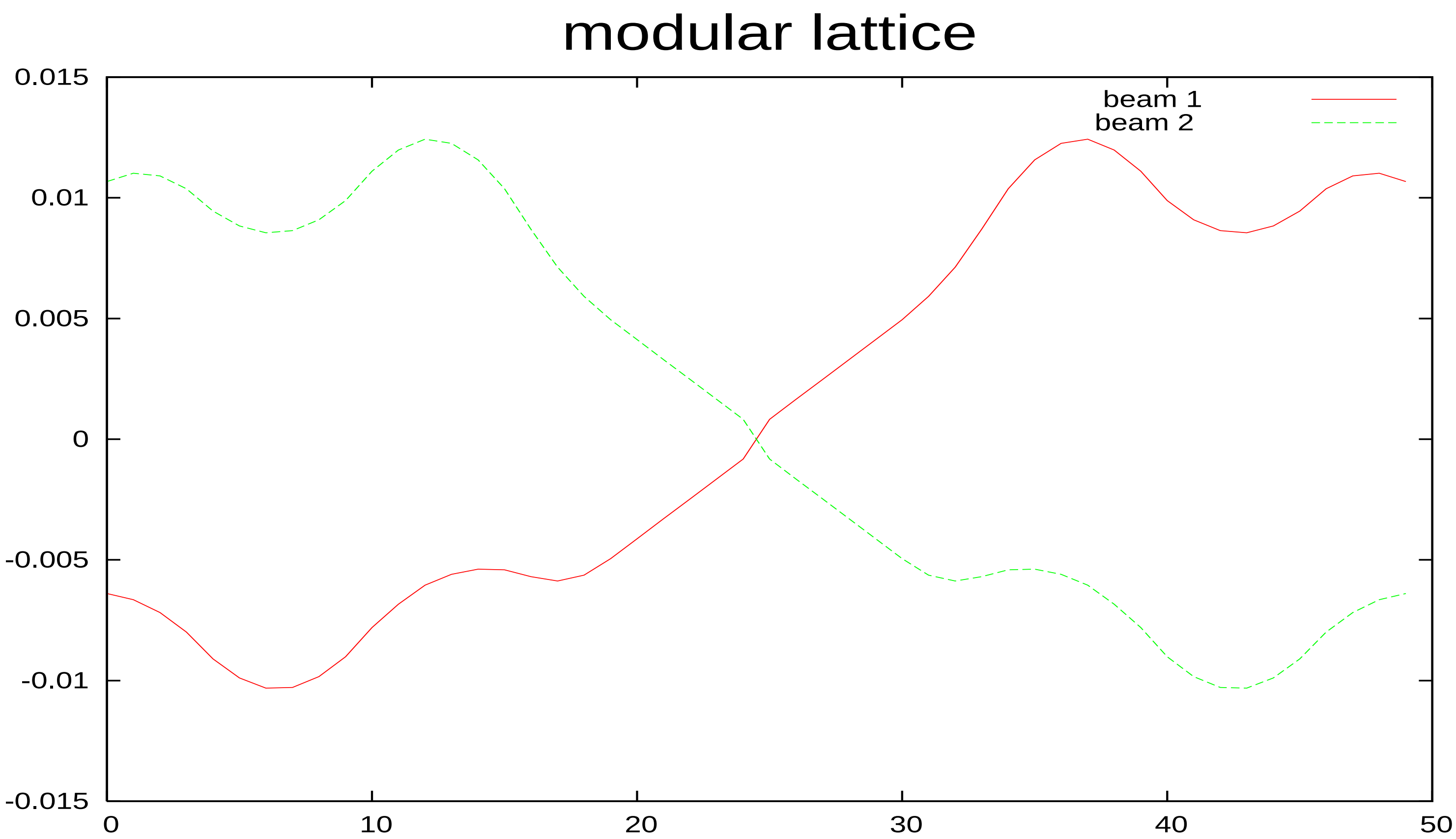
Small beta max:

- **For separation in drift space of 10 σ:**
  - $\alpha \approx \pm$ **220 μrad**
  - **Standard use of MCBX at Q1, strengths all within limits**
  - **More aperture required in triplet**
  - **With $\beta^* = 0.25$: F = 1.81**
  - **Luminosity gain in practice only $\approx$ 47 %**
- **Overall separation similar to nominal optics**

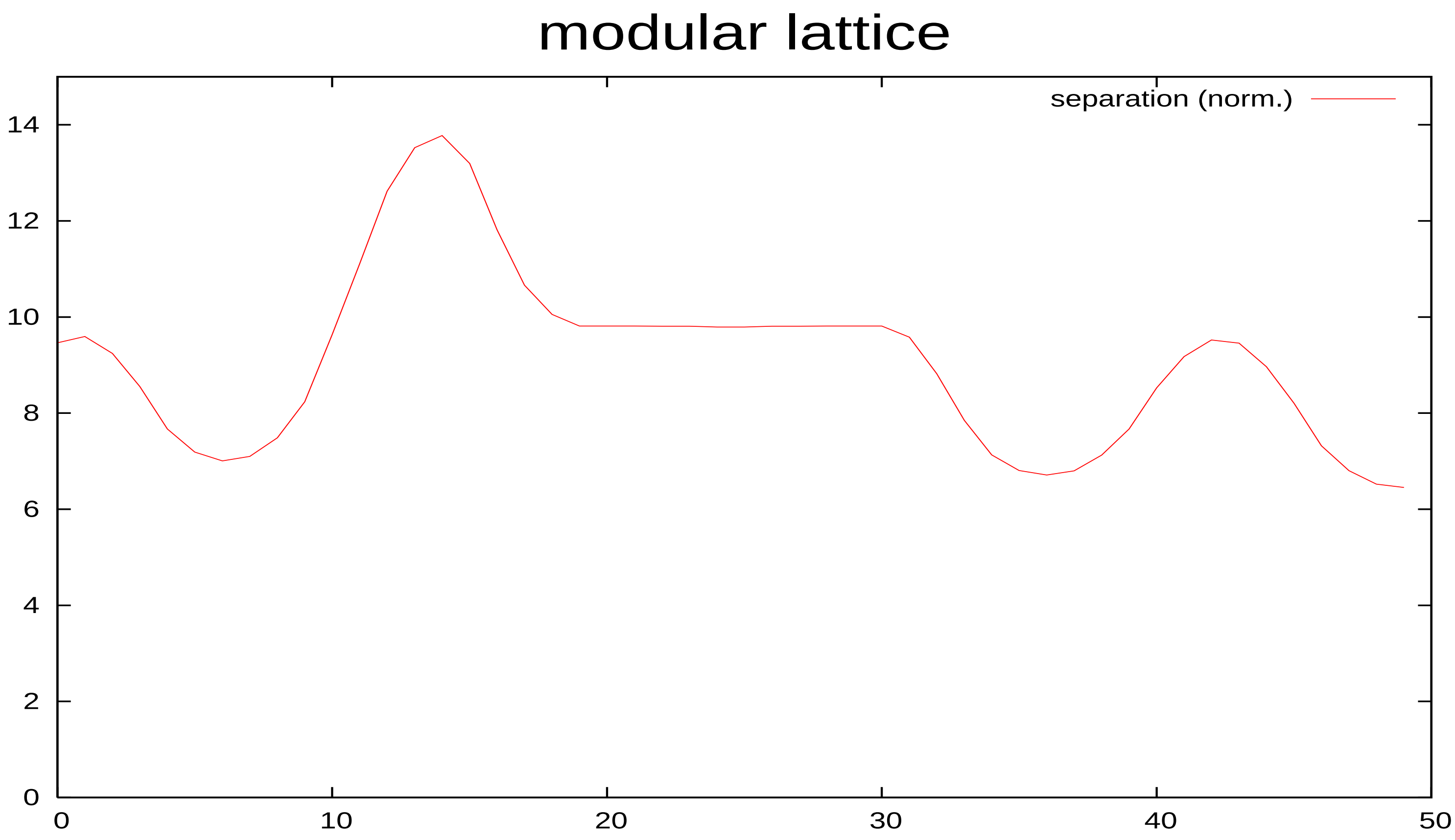
Compact:

- **For separation in drift space of 10 σ:**
  - $\alpha \approx \pm$ **220** μ**rad**
  - **Need MCBX at Q1 and Q2 to keep strengths all within limits**
  - **More aperture required in triplet**
  - **With** $\beta^* = 0.25$: F $= 1.81$
  - **Luminosity gain in practice only** ≈ 47 **%**
- **Overall separation similar to nominal optics**

Modular optics - orbits



Modular optics - normalized separation



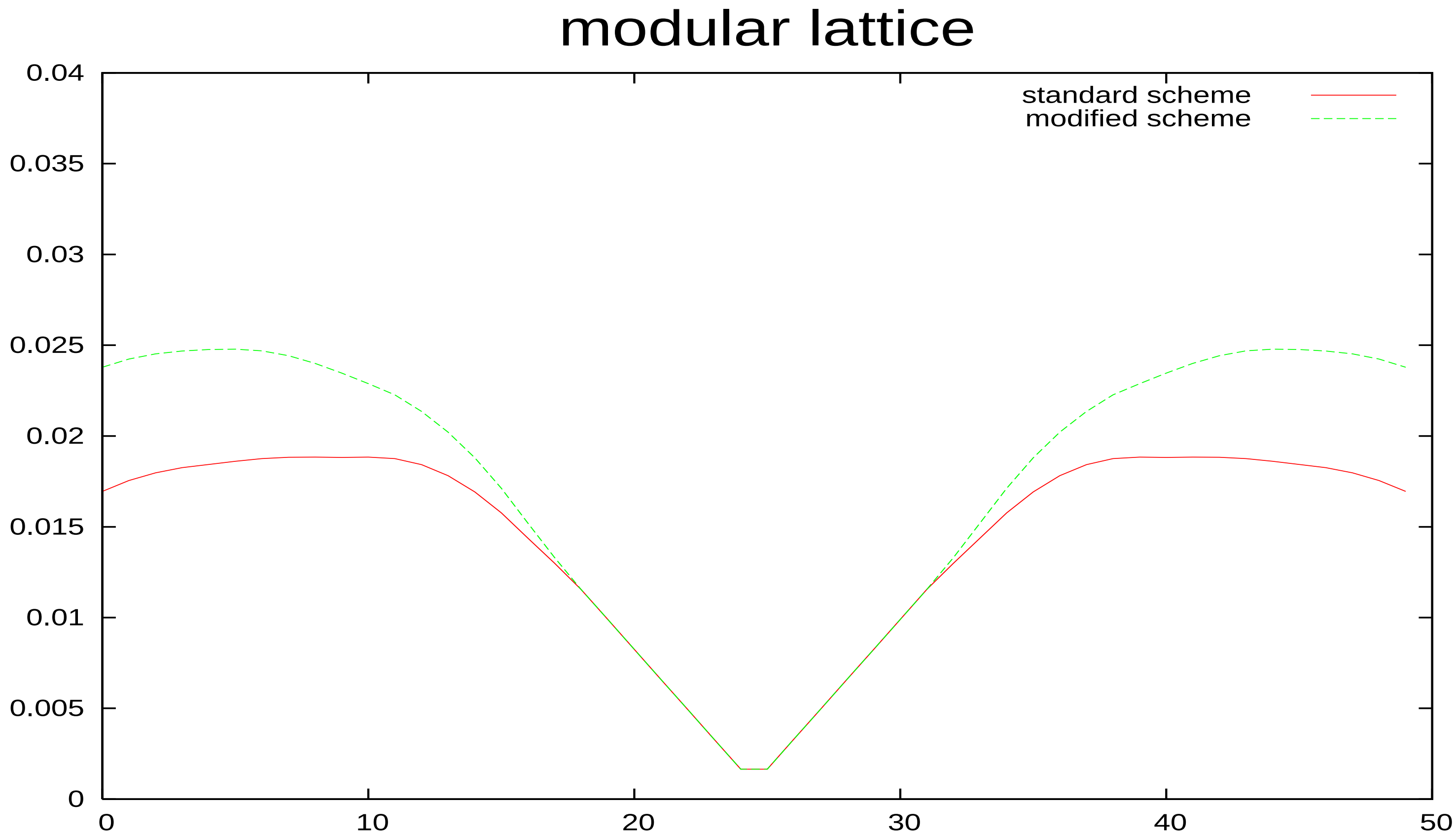
Modular optics crossing

- Crossing in modular optics more delicate:
  - More long range interactions (50 per IP)
  - Region of low separation extended (second drop)
  - Cannot increase crossing angle at IP: no luminosity gain any more !

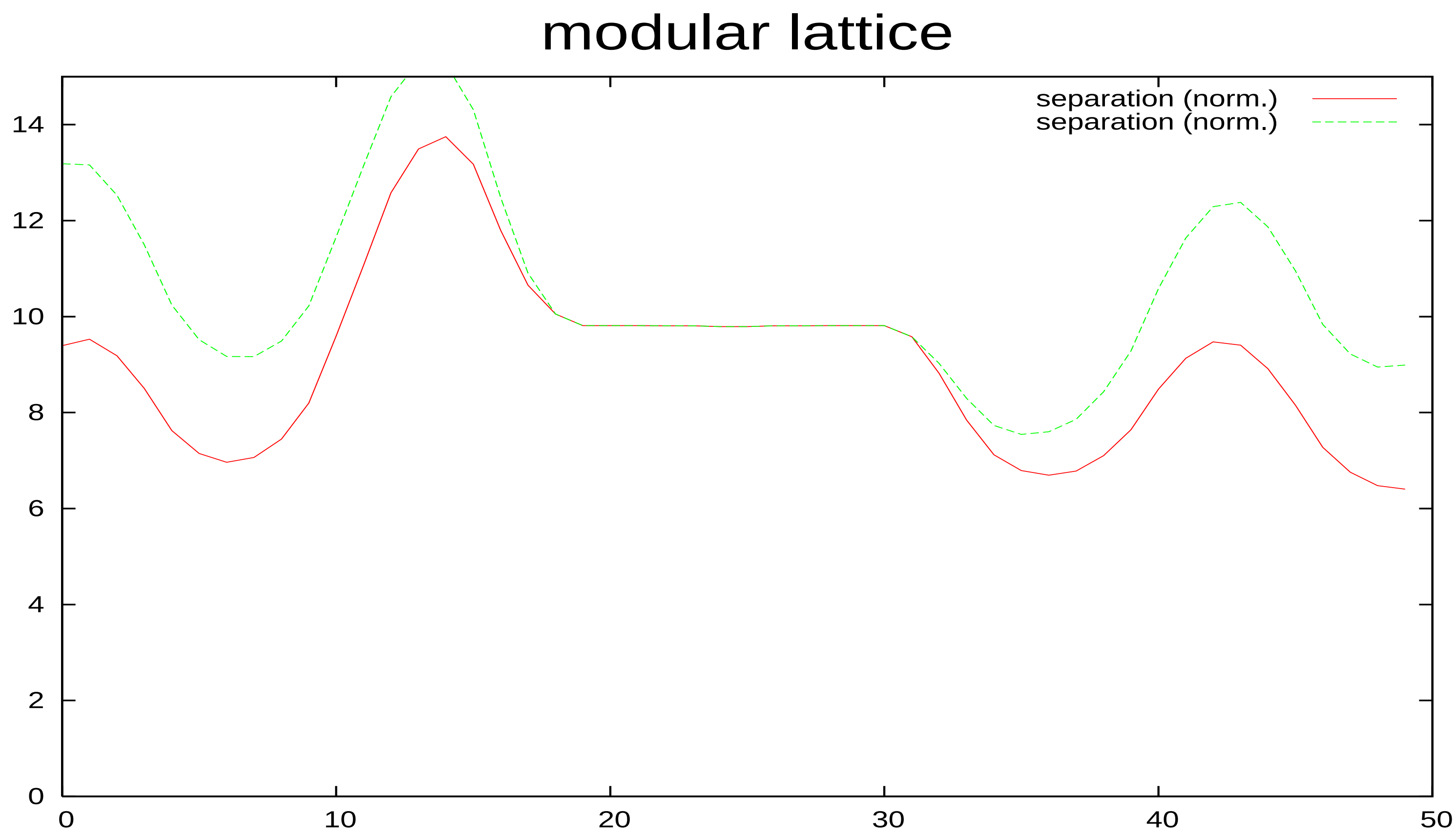
Modular optics crossing

- **Increase separation near D1, keep effective crossing angle at IP small (!)**
  - **Use MCBX to decrease crossing angle at IP (i.e. larger separation for distant parasitic interactions for given crossing angle)**
  - **At the expense of corrector strength behind Q4, Q5, Q6**
  - **Need about double strength in MCBC, MCBY near Q4, Q5, Q6**

Collision scheme - separation



Collision scheme - normalized separation



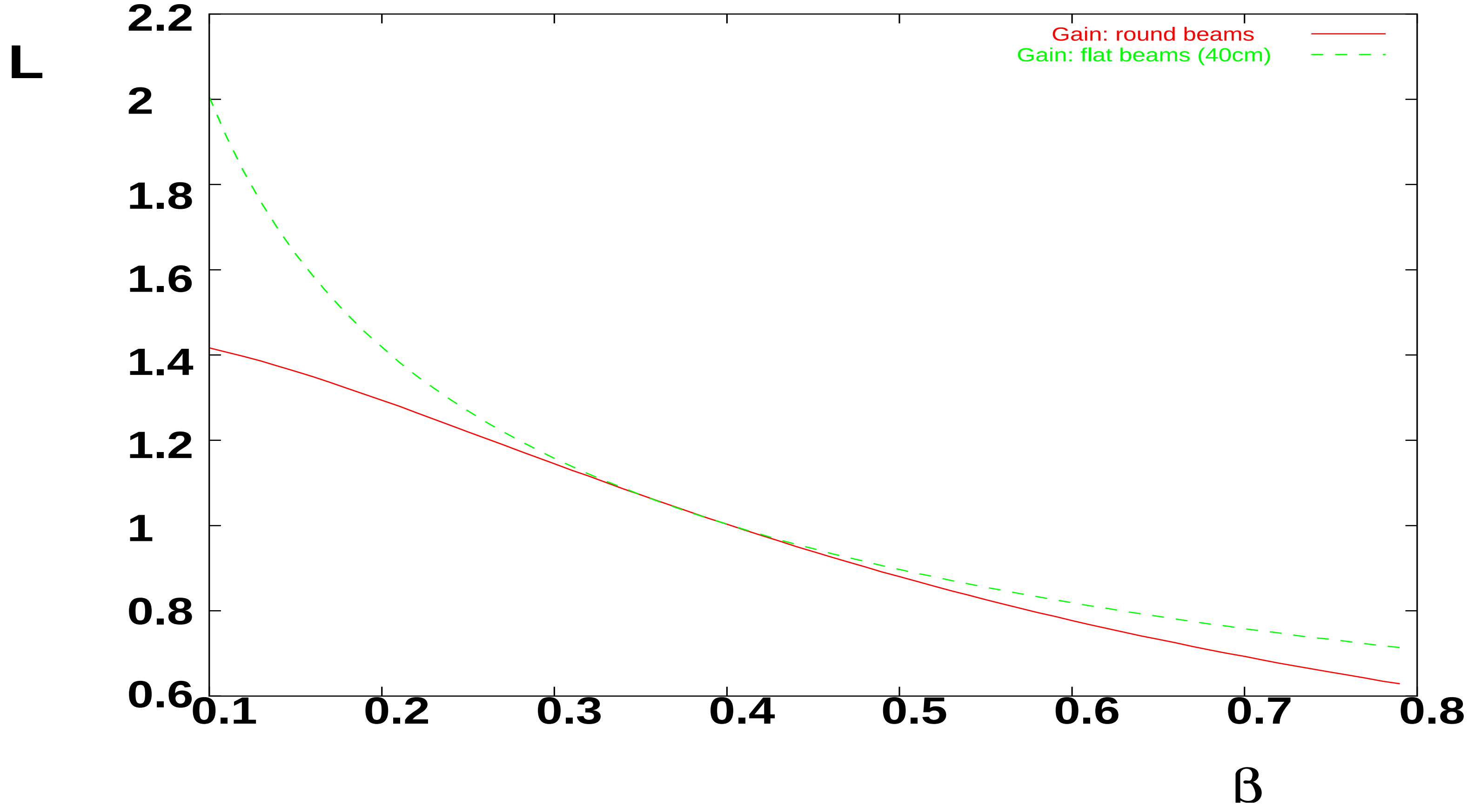
Summary 1

- **Crossing schemes are possible with:**
  - **Increased aperture in triplet and D1**
  - **Much stronger orbit correctors for modular optics**
- **Moderate gain in luminosity**
  - **Beam-beam does not allow reduced crossing angle**
  - **Long range compensation required**

Other options ?

- **Flat beams:**
  - **Increased β^* in plane of separation, smaller crossing angle needed**
  - **Luminosity gain smaller, but also the reduction factor**
  - **SPS in 1990: $(\beta_x, \beta_y) = (0.60$ m, 0.15 m$)$**
  - **but: optically possible ?, coupling ?, ...**

Gain with flat beams - $\beta_x = 0.40$ m



Summary 2

- **Crossing schemes are possible for all options with hardware changes (apertures, correctors)**
- **The $\beta^* = 0.25$ m may help to get to 10^{34}cm^{-2}s^{-1}**
  - → **Large $\mathcal{L}$ increase requires small crossing angle (early separation, long range compensation ?)**
- **Expected behaviour of "compact" and "small β_{max}" similar to nominal**
- **"Modular" or flat beam options need analysis via tracking, if not considered hopeless**