High β optics options for ALICE

Pascal D. Hermes

LCU Meeting

02.10.2012

Thanks to J.M.Jowett, H.Burkhardt, M.Giovannozzi, R.Schicker

Overview

- Intermediate to high β^* optics requested for diffractive physics
- Long running times (parallel to nominal physics at 7 TeV)
- First study with $\beta^* = 30\,\mathrm{m}$, only compatible with 50 ns
- Development of 18 m optics compatible to 25 ns
- Assuming detectors at -180/-220m left and +150/+220m right of IP2

Optics Design Considerations

Design must satisfy LHC requirements and optimize measurement

LHC Requirements

- Quadrupole strength limitations
- B1/B2 ratio constraint
- Separation at first beam encounter $\approx 12\,\sigma$
- Aperture
- Constant IP1-IP5 phase

Measurement optimization

- Compatibility to high luminosity in other IPs $\rightarrow$ Crossing Angle
- Largest possible β^*
- Large β at detector
- IP-detector phase advance as close as possible to 0.25

Which β^* ?

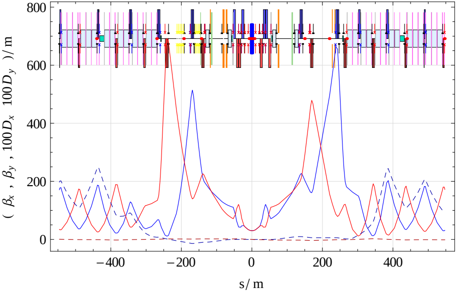
Ingredients to determine β^*

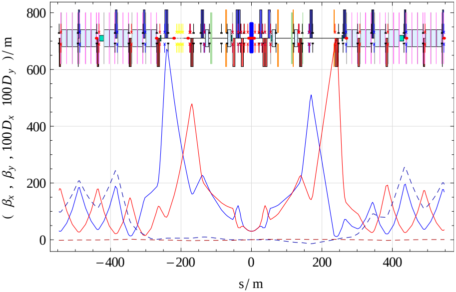
- DR Emittance : 3.75 μm rad
- Crossing Angle : 300 μrad
- Bunch spacing : 50 ns/25 ns
- Required Separation

$$\beta^* \approx \begin{cases} 68\,\text{m} & \text{for 50ns} \\ 18\,\text{m} & \text{for 25ns} \end{cases}$$

30 m optics suitable for 50ns, developing 18 m for 25ns

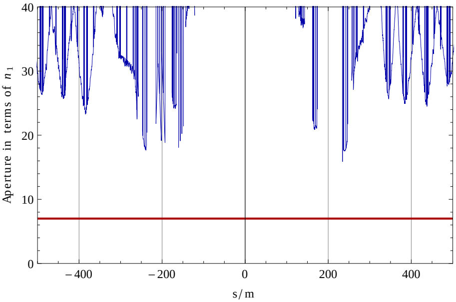
30 m optics

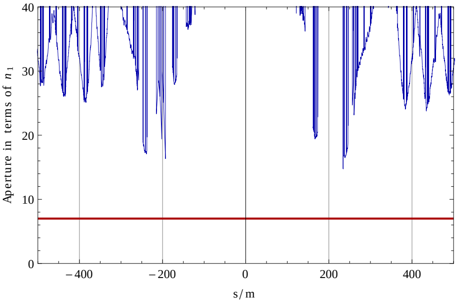




- Triplet strength reduced
- With 300 μrad and DR emittance : separation for 25 ns too small
- IP-RP220 phase advance is 1/3
- Phase advance reduced by : 0.466/0.414 (B1) and 0.486/0.431 (B2)

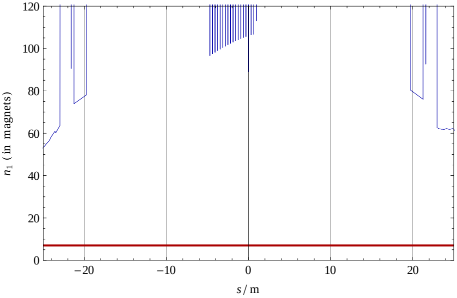
30 m n_1 aperture with all crossing bumps switched on



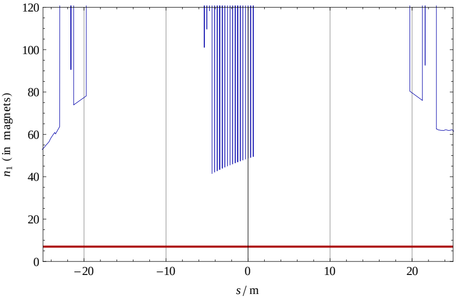


30 m n_1 aperture with all crossing bumps switched on

Present ALICE beam pipe



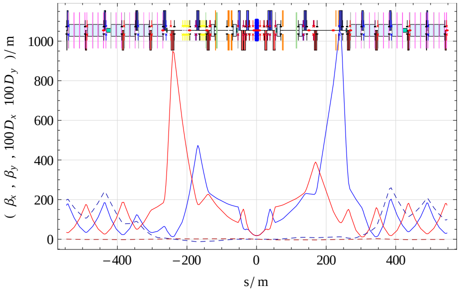
New ALICE beam pipe (LS2)
(MAD files by M. Giovannozzi)

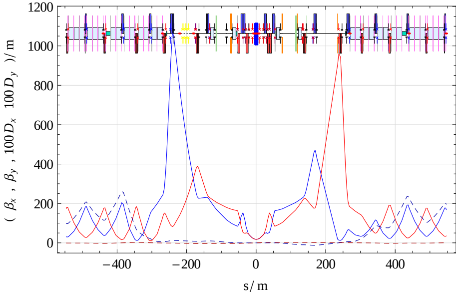


18 m optics

- Matched optics with $\beta^* = 18\,\text{m}$
- Rematchings to
  - Reduce certain quadrupole strengths
  - Optimize B1/B2 ratio
  - Maximize phase advance over IR2
    (minimize required tune compensation)
  - Minimize IP-detector (RP220) phase advance
- Separation $> 11.6\,\sigma$ for $\theta_C = 300\,\mu\text{rad}$

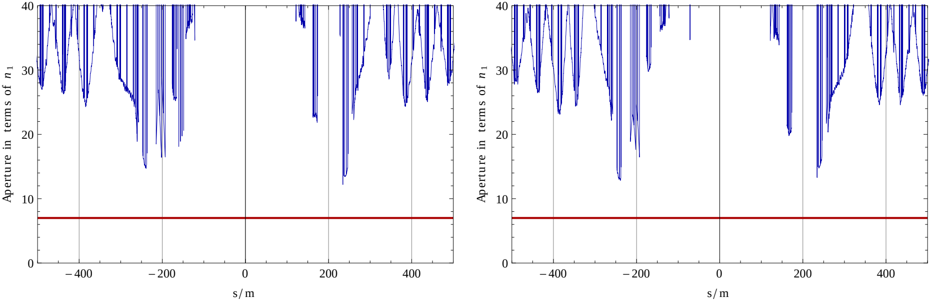
18m optics





- Triplet strength reduced
- Phase advance reduced by 0.475/0.457 (B1) and 0.468/0.453 (B2)
- IP-RP220 phase advance is 0.34
- Quadrupole strengths moderate ; B1/B2 constraint fulfilled

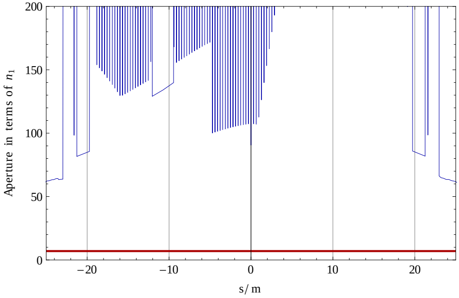
18m n_1 aperture with all crossing bumps switched on



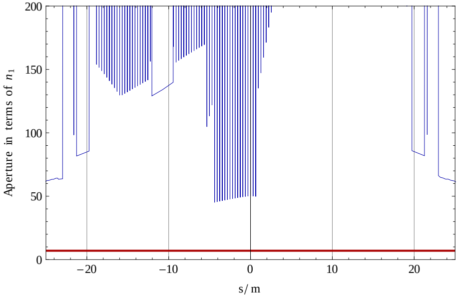
- Aperture ok, can still check for new ALICE beam pipe

18m n_1 aperture with all crossing bumps switched on

Present ALICE beam pipe



New ALICE beam pipe (LS2)
(MAD files by M. Giovannozzi)

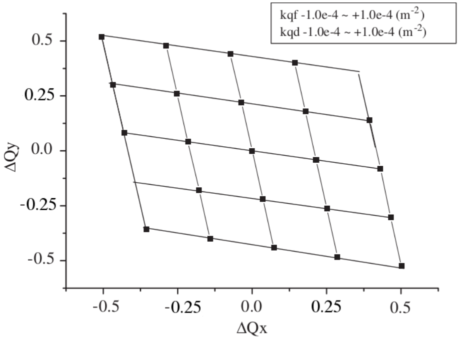


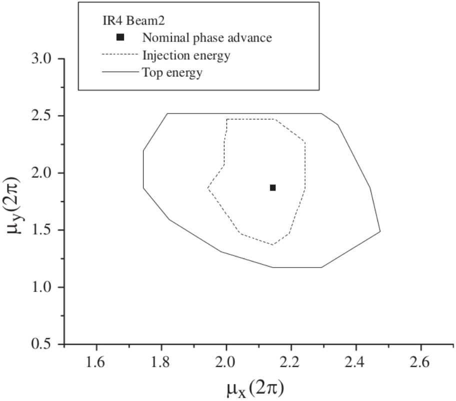
Tune compensation

- Matched for 0.34 / 0.333 IP-detector (RP220) phase advance
- Internal compensation very limited (B1/B2 constraint)
- Significant reduction of phase advance over IR
- Very large tune compensation required
- IP1-IP5 phase advance constraint : 0.25
  $\rightarrow$ only half of the ring available for compensation

β^*/m	10	18	30
$\Delta\mu_x^{\text{IP-Q6}}$	0.55	0.35	0.34
$\Delta\mu_y^{\text{IP-Q6}}$	0.52	0.35	0.34
ΔQ_x	0	0.48	0.47
ΔQ_y	0	0.46	0.41

Tune compensation strategy

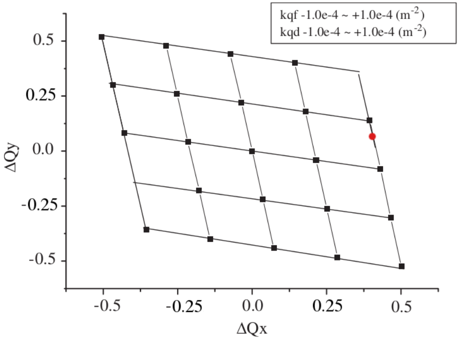


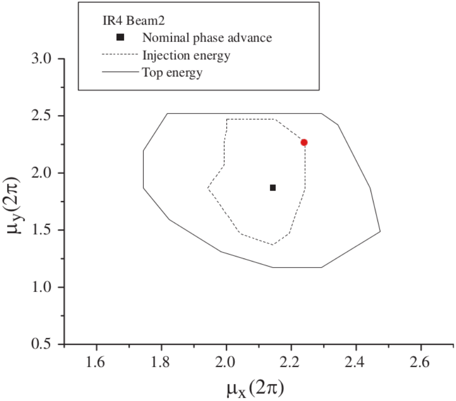


Tunability ranges of main arcs (half of the ring) and IR4 for Beam 2
Concrete compensation strategy if ALICE is interested in implementation

Figures from : M.Aiba et. al. Optics flexibility in the LHC at top energy, Proceedings of EPAC 2008

Tune compensation strategy





Tunability ranges of main arcs (half of the ring) and IR4 for Beam 2
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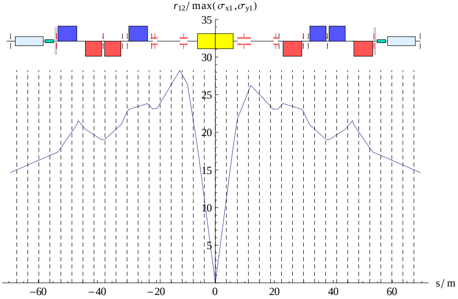
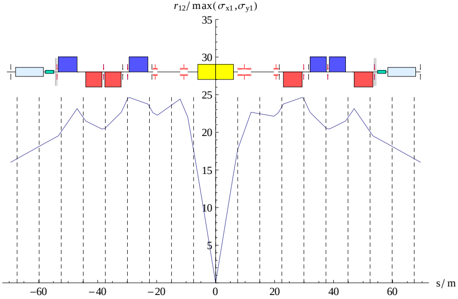
Separation

18m optics with $\theta_C = 300\,\mu$rad



30 m optics with $\theta_C = 300\,\mu$rad



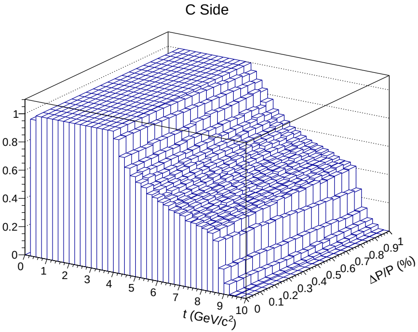
Beam-Beam tune shift parameter

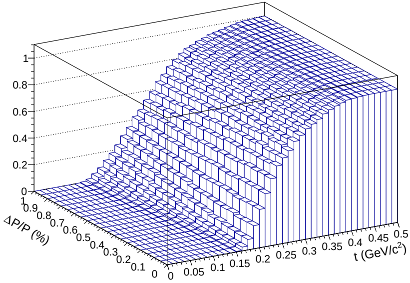
β^*	Bunch spacing	θ_C/μrad	$\xi_{x,y}$
10	25 ns	175.8	$9.9 \cdot 10^{-5}$
18	25 ns	300	$5.5 \cdot 10^{-5}$
30	50 ns	300	$2.4 \cdot 10^{-5}$

- ξ evaluated for first beam encounter
- Thanks to larger crossing angle & bunch spacing smaller than for nominal IR2 optics

Acceptance Plots

Acceptance in function of t and ξ for Beam 1 $(x, y > 10\,\sigma)$

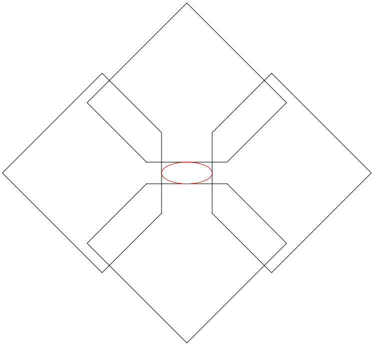




Depending on model used for the simulation

Acceptance Plots

Matrix elements allow acceptance calculations



Simulation : Detection conditions

- Lower limit :
  $x, y > 9, 10, 11, 12\,\sigma$?
- Upper limit : $x, y < 26\,\text{mm}$

Diffractive Parameters

- 4-momentum transfer

$$t = -p^2\,\theta^2 \qquad (1)$$

- Relative momentum loss

$$\xi = \frac{\Delta p}{p} \qquad (2)$$

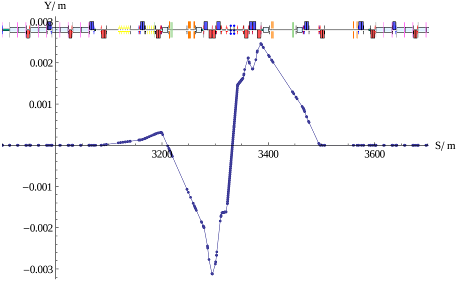
What are considerable values for the lower limit during physics runs ?

Summary

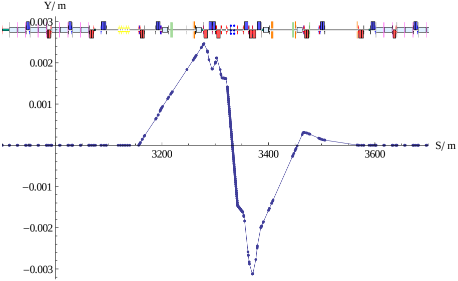
- Two optics designs with β^* of 18 m and 30 m
- 18 m compatible to 25 ns bunch spacing
- Aperture is ok for both, old and new ALICE beam pipe
- Tune compensation :
  first analysis , required compensation close to the limits
- More detailed study could indicate concrete limits for phase advance
- Acceptance plots link to physics
  See if optics will be interesting for ALICE
  Presentation with R. Schicker on ALICE week next week

Crossing Scheme

Beam 1



Beam 2



- Full crossing angle $\theta_C = 300\,\mu$rad