High β* 2015

by Helmut Burkhardt

with input from Riccardo de Maria for the optics file repository and VdM synergy

and Tatiana Pieloni for the beam-beam team

Basic strategy 2015 : priority for high-energy 25 ns commissioning,

- **time for physics production and MDs reduced**
- **~1 week for special runs VdM + high-β* 90 m**

Very high β* > 1000 m after 2015 when Q4 cables installed in both IP1&5

Start from known optics, only change what is needed, minimize extra setup time

Maximize synergies with standard optics and VdM β* ~ 20 m

Use the existing de-squeeze 11 --> 90 m

New: Crossing angle for more bunches as requested by TOTEM

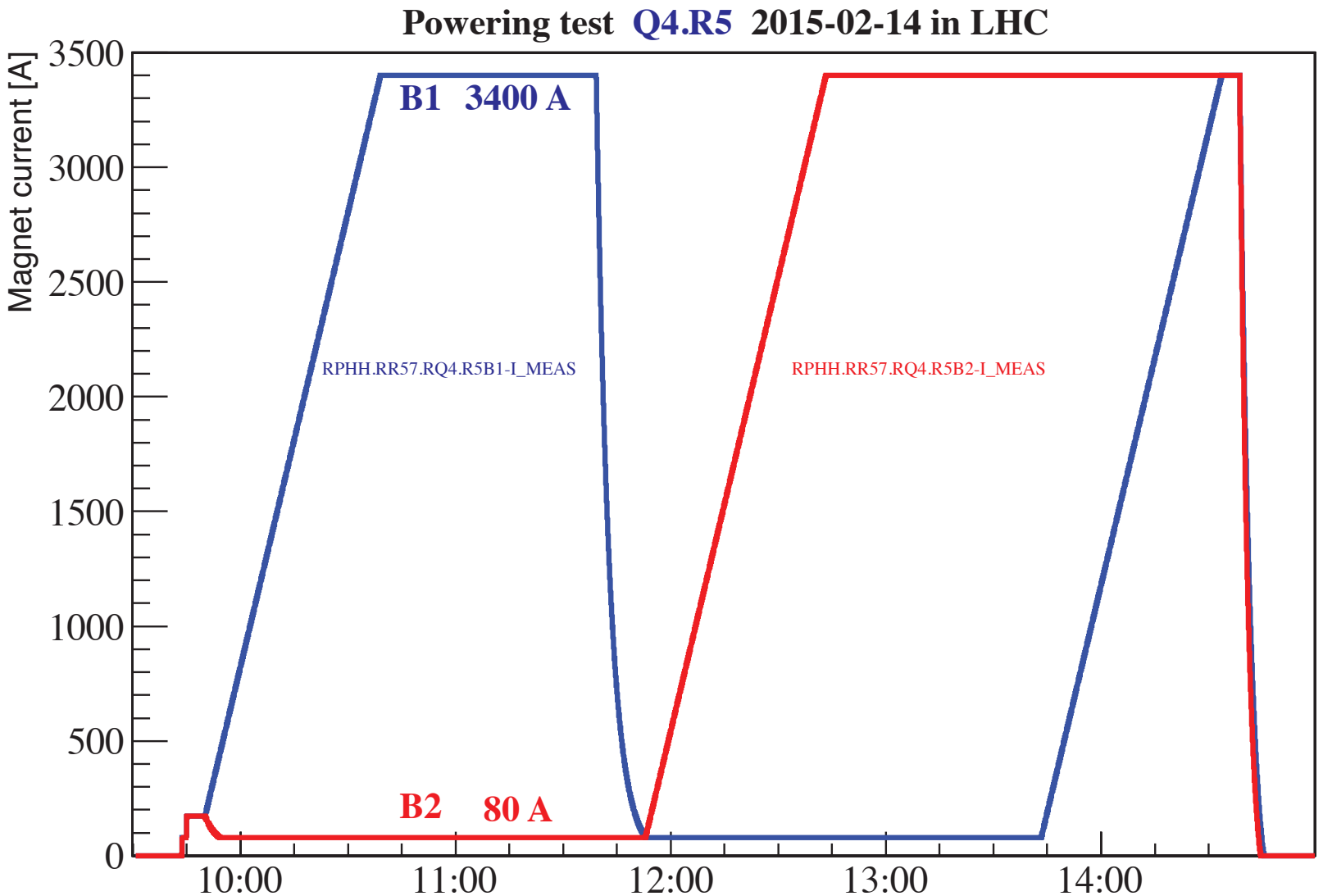
Make crossing angle and separation bumps compatible with standard physics / VdM 2015 : use all 3 MCBX at same current

Naming conventions within madx files, many changes from V6.503 to run II

directory : /afs/cern.ch/eng/lhc/optics/**runII/opt_med**

Good recent news - recabling Q4 in IR5

more : my presentation in TREX#6 26/2/2015

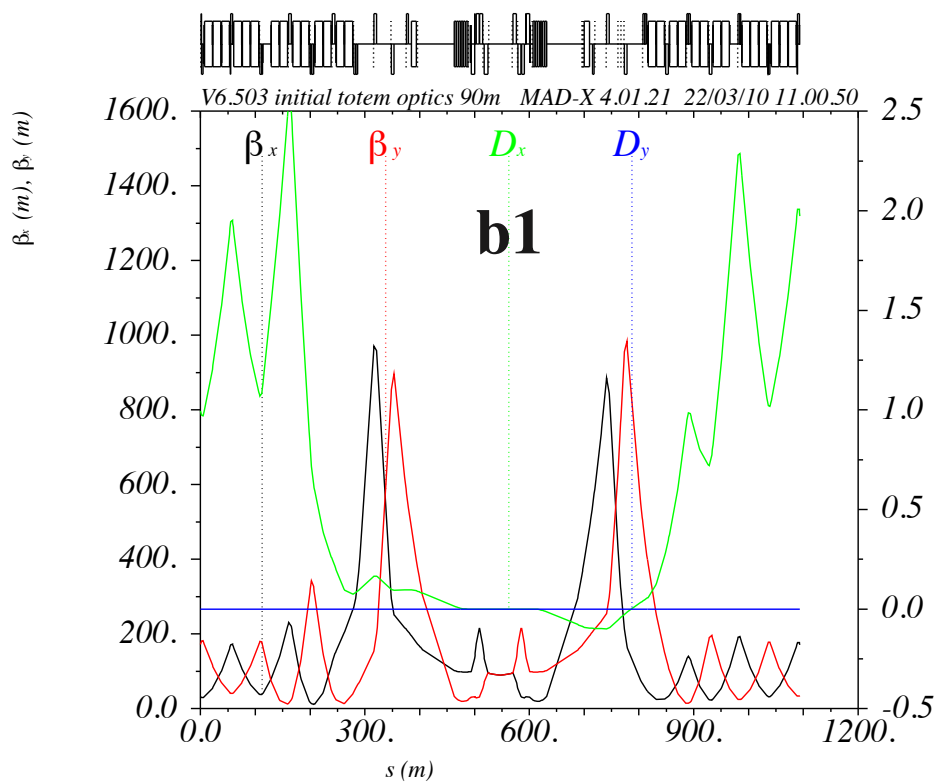


Works as expected -- apply to Q4 in IP1 asap !! (ECR in prep.)

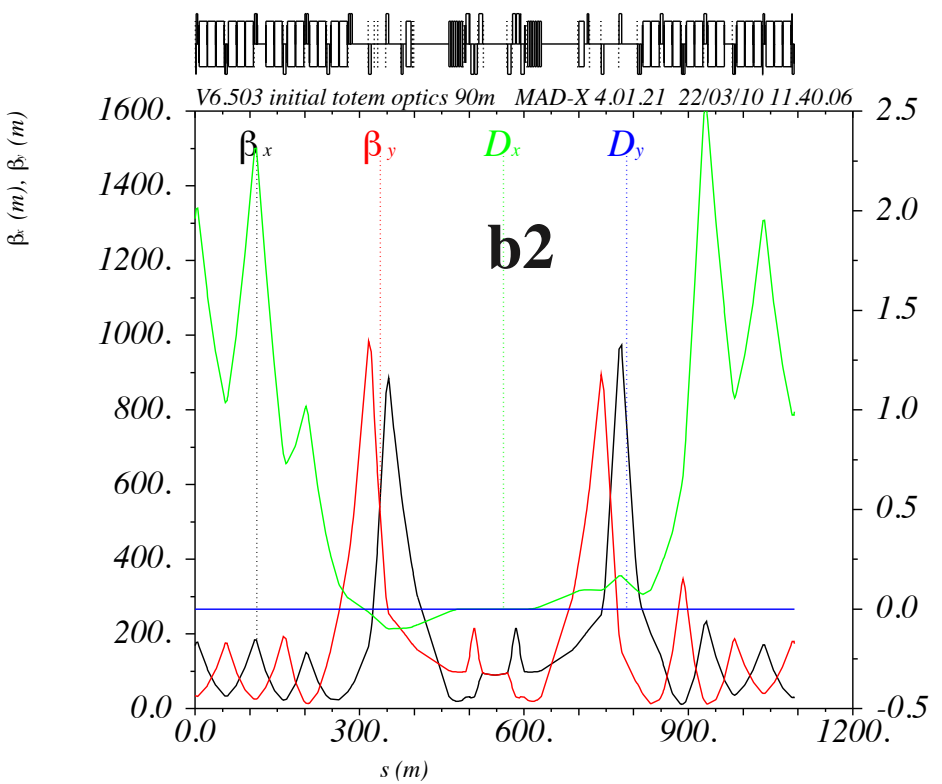
Standard 90 m optics

π / 2 in y to roman pot and ~ π in *x* and, as in 2011/2012, shown for IP5, RP at 220 m

`V6.503/HiBeta/ IP1_beta90.str, IP5_beta90_2010.str --> runII/opt_med/ IR1/ir1_90000.madx IR5/ir5_90000.madx`



ΔQx = 0.222 ΔQy = 0.055



ΔQx = 0.220 ΔQy = 0.053

With current cabling required to have quad strength ratios within **0.5 < b1/b2 < 2.0**

kq4.l5b1/	kq4.l5b2=	0.970945
kq5.l5b1/	kq5.l5b2=	1.04019
kq6.l5b1/	kq6.l5b2=	1.05394
kq7.l5b1/	kq7.l5b2=	1.5816
kq8.l5b1/	kq8.l5b2=	1.33077
kq9.l5b1/	kq9.l5b2=	1.03071
kq10.l5b1/	kq10.l5b2=	0.94919

kq4.r5b1/	kq4.r5b2=	1.10542
kq5.r5b1/	kq5.r5b2=	0.961367
kq6.r5b1/	kq6.r5b2=	0.938599
kq7.r5b1/	kq7.r5b2=	0.525421
kq8.r5b1/	kq8.r5b2=	0.571775
kq9.r5b1/	kq9.r5b2=	0.964224
kq10.r5b1/	kq10.r5b2=	1.05372

Pre-collision - parallel separation

Standard injection, ramp, de-squeeze IP1 and IP5, first part already used for VdM

Technical changes required compared to run1 de - squeeze :

run1 : ± 2 mm constant separation in IP1 & 5 through de-squeeze to 90 m,
beyond strength limits at 7 TeV, beams size reduced $(1/\sqrt{E})$,

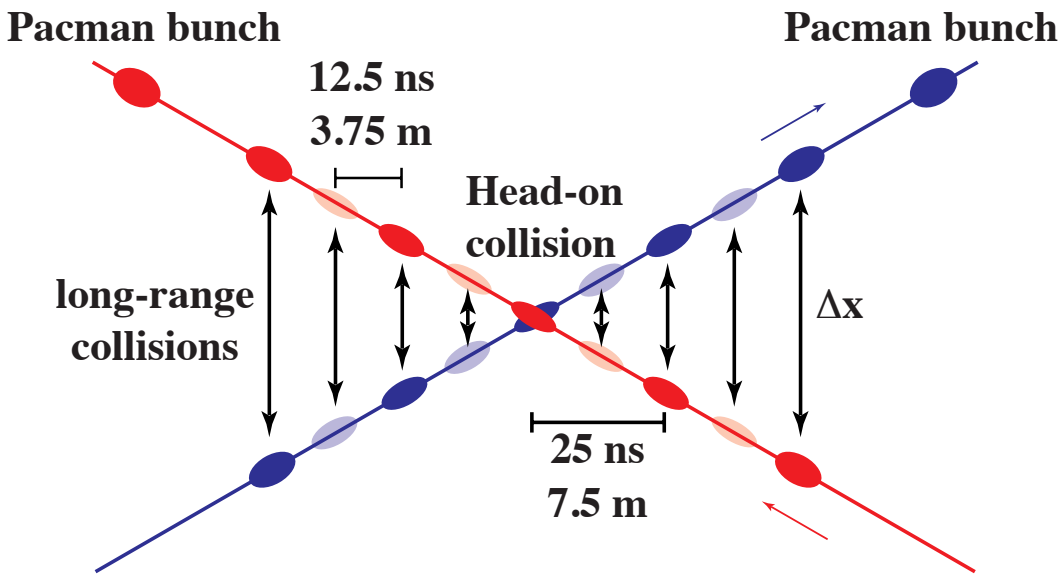
run2 : ± 1 mm constant separation in IP1 & 5 through de-squeeze to 90 m

At p = 6.5 GeV, β* = 90 m

at ε_N = 3.75 µm σ* = 220.72 µm Δsep = ± 1 mm 8.8 σ

at ε_N = 2 µm σ* = 161.19 µm Δsep = ± 1 mm 12 σ

Principle of separation by crossing angle at higher β*



Low β* (< L*)

beam size and separation increase ∝ Δs,

⇒ separation in units of σ about constant around IP

all parasitic crossings adding up with similar contribution

Instead high β* :

beam size ~ constant = σ*, separation in σ increases as ΦΔs

where Φ is the crossing angle, dominated by 1st parasitic crossing

100 ns bunch spacing 4× more separated than 25 ns

and negligible contribution from next 200, 400 ns ...

β* = 90 m, with crossing angle

We had one higher-luminosity fill 2836 with 112 bunches / beam on 13/07/2012

Without crossing angle : Maximum #bunches = 156

For 2015 :

Matching crossing angle bumps using the default planes and correctors (up to Q6) for the existing 90 m optics

Vertical crossing in IP1

Horizontal crossing in IP5

Strength files for tests / simulations made available to TOTEM, ALFA in spring 2014

Now finalized with Riccardo for maximum synergy with standard optics and VdM

6.5 TeV, separation in σ for ±50 μrad crossing angle

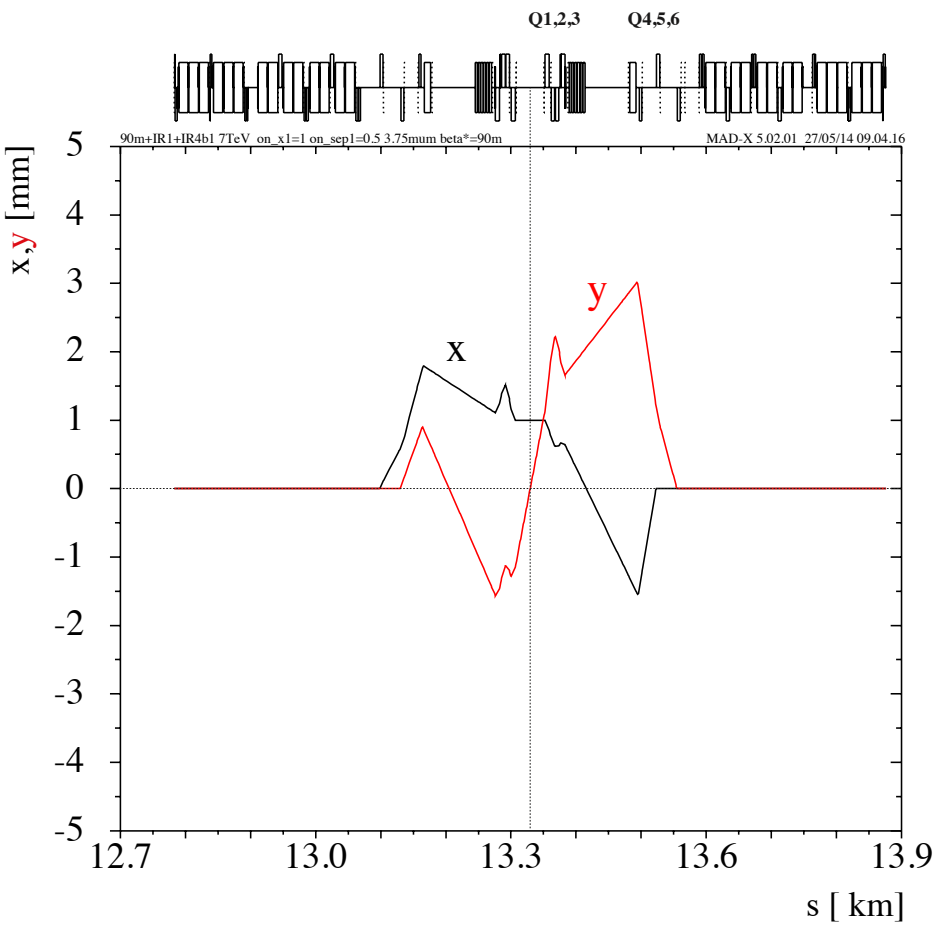
spacing in ns	sep in σ	sep in σ	max # bunches
	2 μm	**3.75 μm**	
25	2.4	1.8	2808
50	5.5	4	1404
75	8.3	6.1	936
100	**11**	**8**	**702**

100 ns good choice :
- **separation**
- **ALFA (and TOTEM) electronics**
- **RF of injectors**

Separation and Crossing bumps at 90 m, IR1, IR5

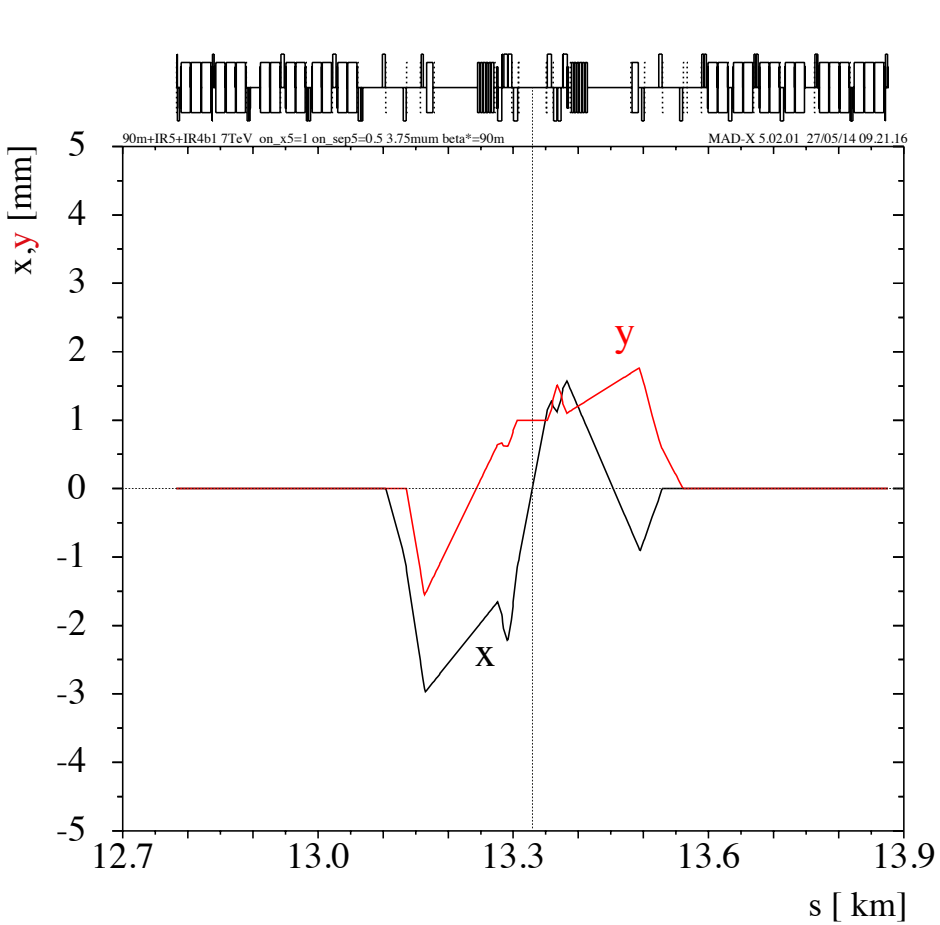
IR1, ATLAS-ALFA

Vertical crossing



IR5, CMS-TOTEM

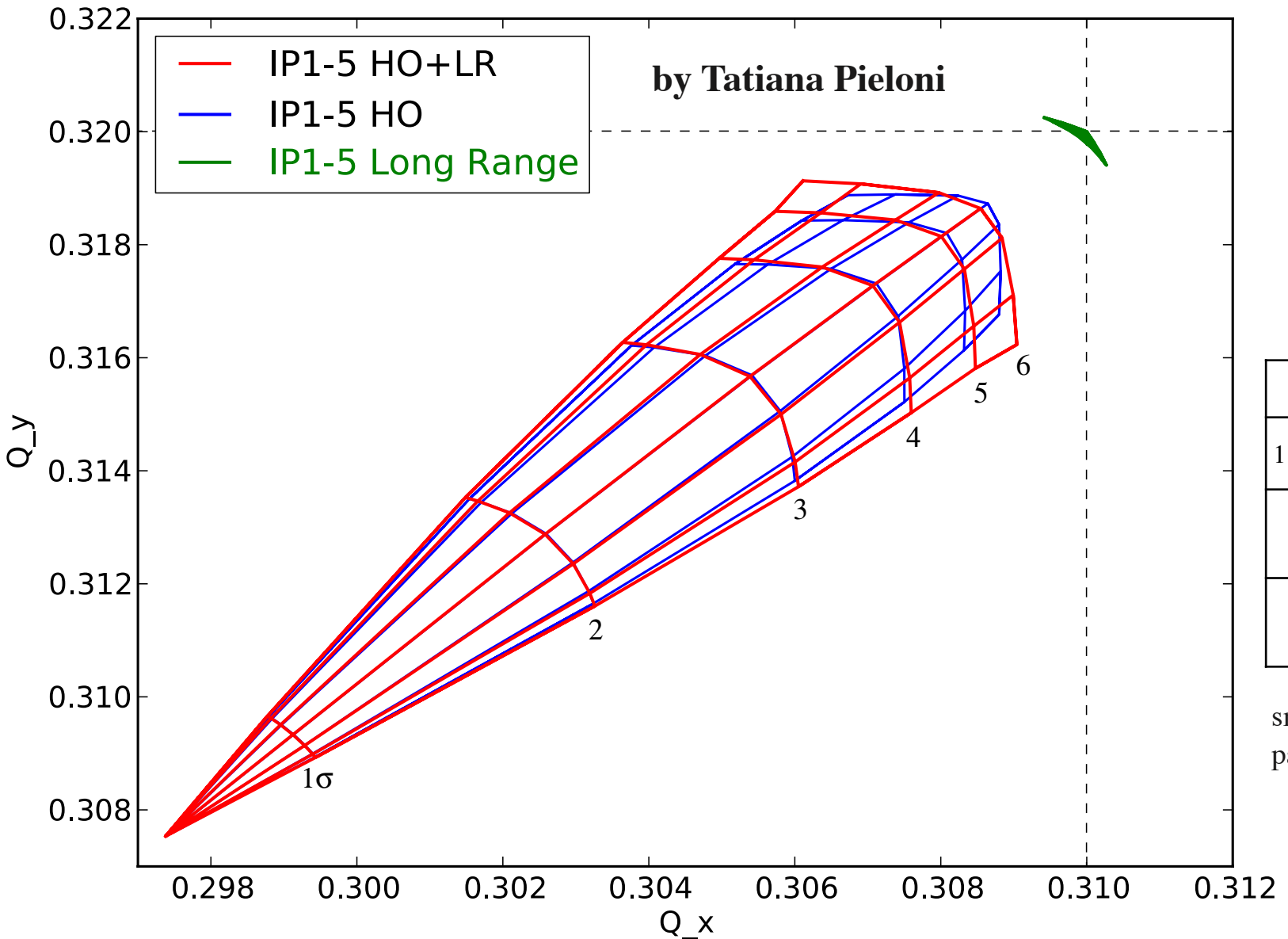
Horizontal crossing



Shown for ± 1 mm separation (end of de-squeeze)
± 50 µrad (half) crossing angle

Beam-beam footprint, 90 m, 2015

100 ns spacing, 10^{11} p/bunch, 6.5 TeV, ±50μrad crossing angle, 2μm emittance



Head on b.b.
tune shift parameter ξ
round beams
independent of β*

$$\xi = -\frac{r_c\, N}{4\pi\, \epsilon_N}$$

N	ε_N [μm]	-ξ
1.15E+11	3.75	0.00375
7E+10	2	0.00427
1E+11	2	0.0061

small emittance decreases parasitic, increases head-on

Checking - files, procedures..

Tedious and time consuming (all names, changed, strength slightly changed...)

final versions expected to go on http://lhc-optics.web.cern.ch/lhc-optics/www/

but also useful to spot possible issues -- of more general relevance

Additional complication for high-β optics : global tune compensation

90m IR1+IR5

Δqx = 0.4455, ΔQy = 0.1097 with main quads

remaining ± 0.002 differences b1, b2 with trim quads

Use 90 m files in runII/opt_med IR1/ir1_90000.madx IR5/ir5_90000.madx

with currently on_x1 := 0.8333 ; on_x5 := 0.8333 ; to get ±50 μm crossing angle

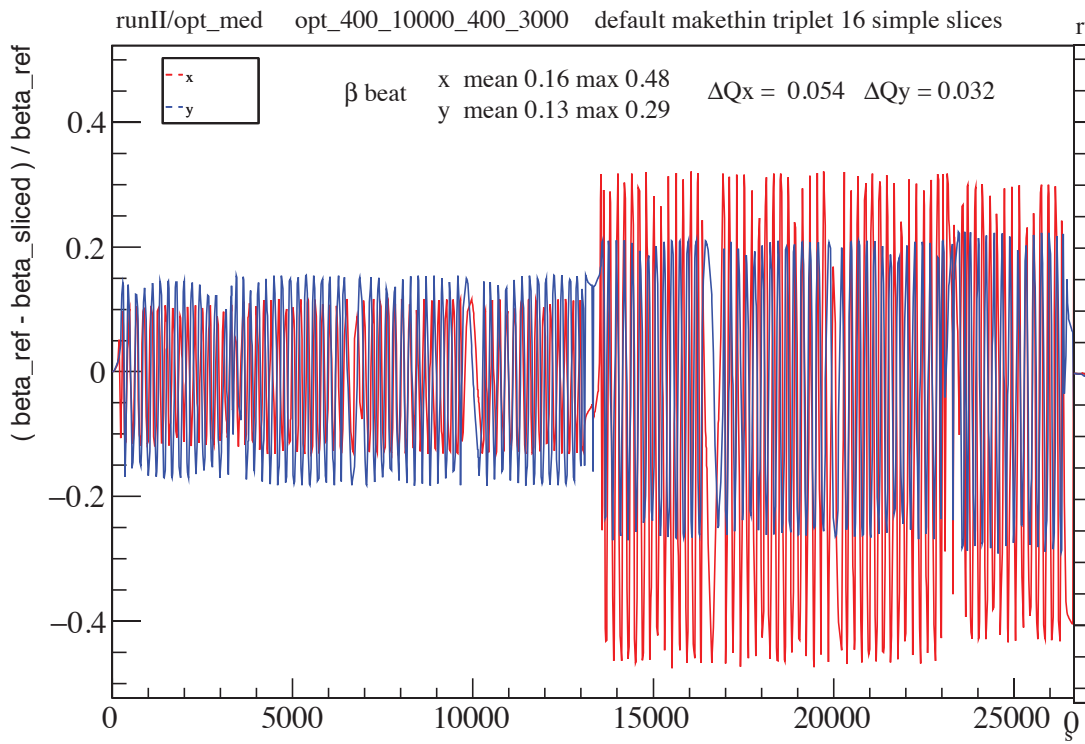
Thin optics version required for tracking, beam-beam (footprint)

- needed for any optics considered, including high-β
- using a single sliced runII/opt_med/V6.5.thin.seq

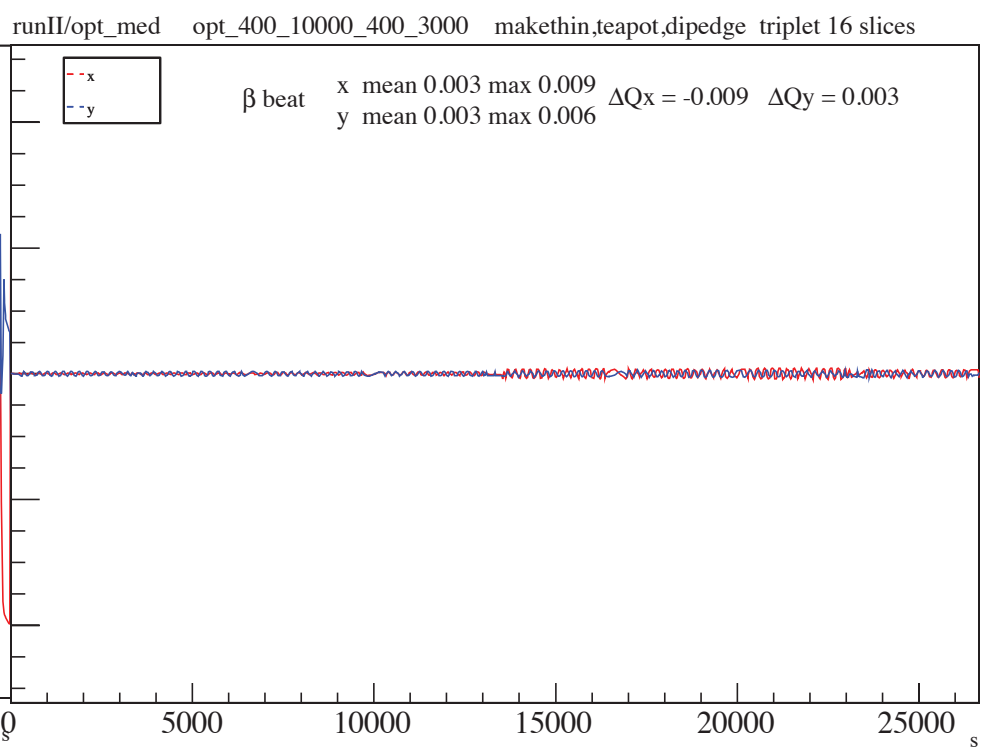
checked and improved, relevant for all 2015 optics ➪

runII/opt_med/V6.5.thin.seq

(old) default



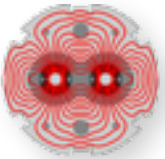
TEAPOT, same # slices



16 slices for Q1-Q3, ~15% beta-beat (max ~50%) **with (old) default (simple)**

reduced to < 1% with TEAPOT slicing

Summary, outlook, high-β*



2015 : files prepared, checked and passed on to OP

re-commissioning 90 m, start with few bunches, then more with crossing angle

2016 : cables installed both IR1 & IR5 TOTEM/ALFA

short cross section measurement runs at very high β* > 2000 m

more extended high luminosity run at 90 m

at some point will pay off to speed up by higher injection β* or

combined ramp & de-squeeze

90 m likely to be continued in 2017, 2018, with

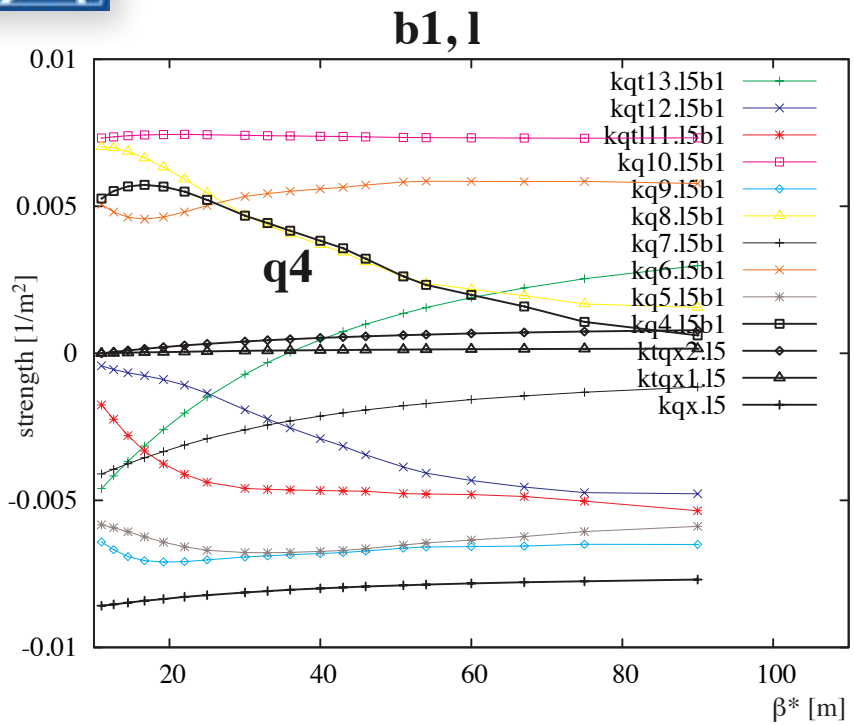
new very fast (10ps) timing detectors to deal with higher pile-up

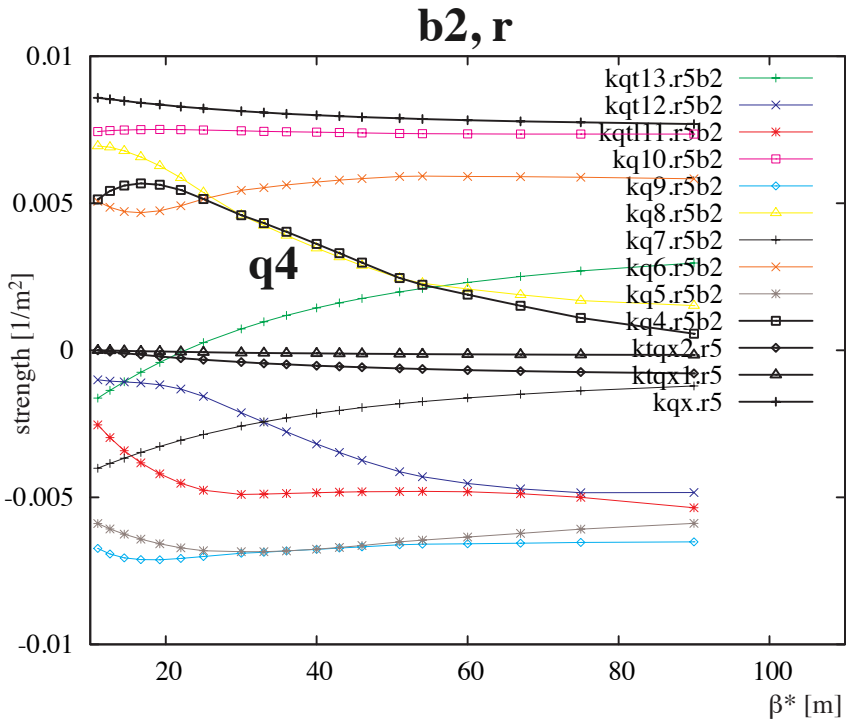
and other forward detectors (AFP or similar) outside the beam pipe

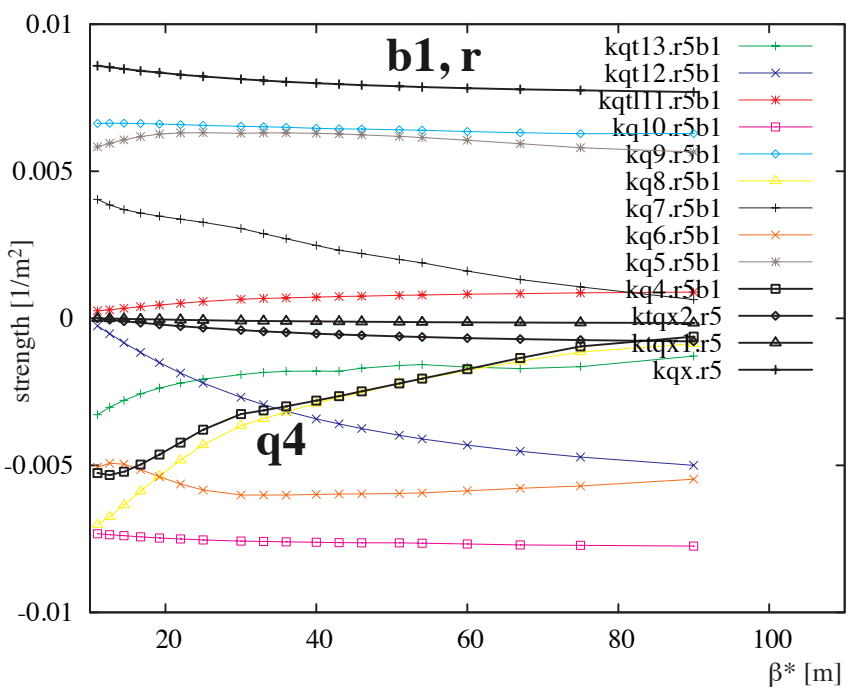
2022 : high-β program expected to end with LS3

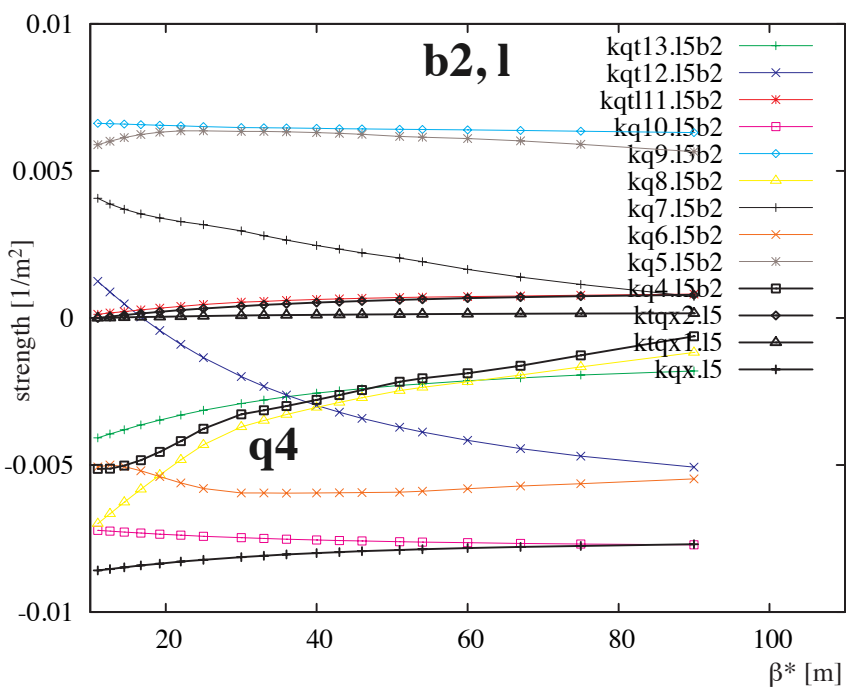
Backup

Quadrupole strength evolution during de-squeeze 11- 90 m









TOTEM request

Mario Deile LPC Meeting 18.09.2013

reminder from LPC 11.06.2013

1. Substantial running at $\beta^* = 90$ m
   - early commissioning at new energy while LHC lumi is low
     → elastic scattering + total cross-section
   - introduce crossing-angle
     → run with ~ 1000 small bunches (7×10^{10}) → low pileup ($\mu \sim 5\%$) at $L \sim 10^{31}$ cm^{-2} s^{-1}
     → study Central Exclusive Production with CMS
     request: 2 x 1 week

2. Very high β^* ($\geq$ 2500 m to reach CNI region)
   Will try to get the magnet cables installed during LS1.

3. Low β^*: Insertion tests with consolidated horizontal RPs

4. RP Operation at any lower-energy or ion runs requested by others