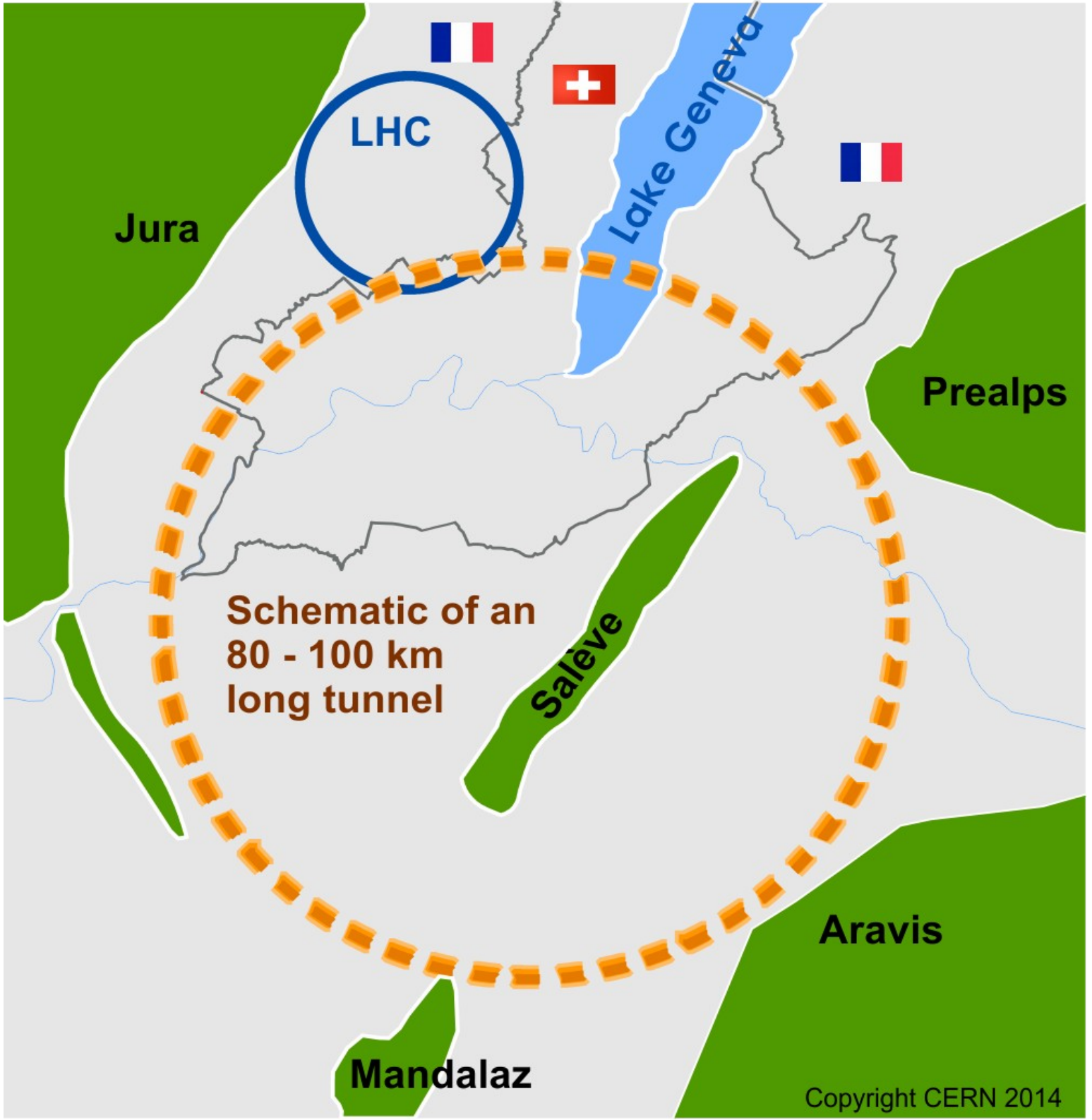
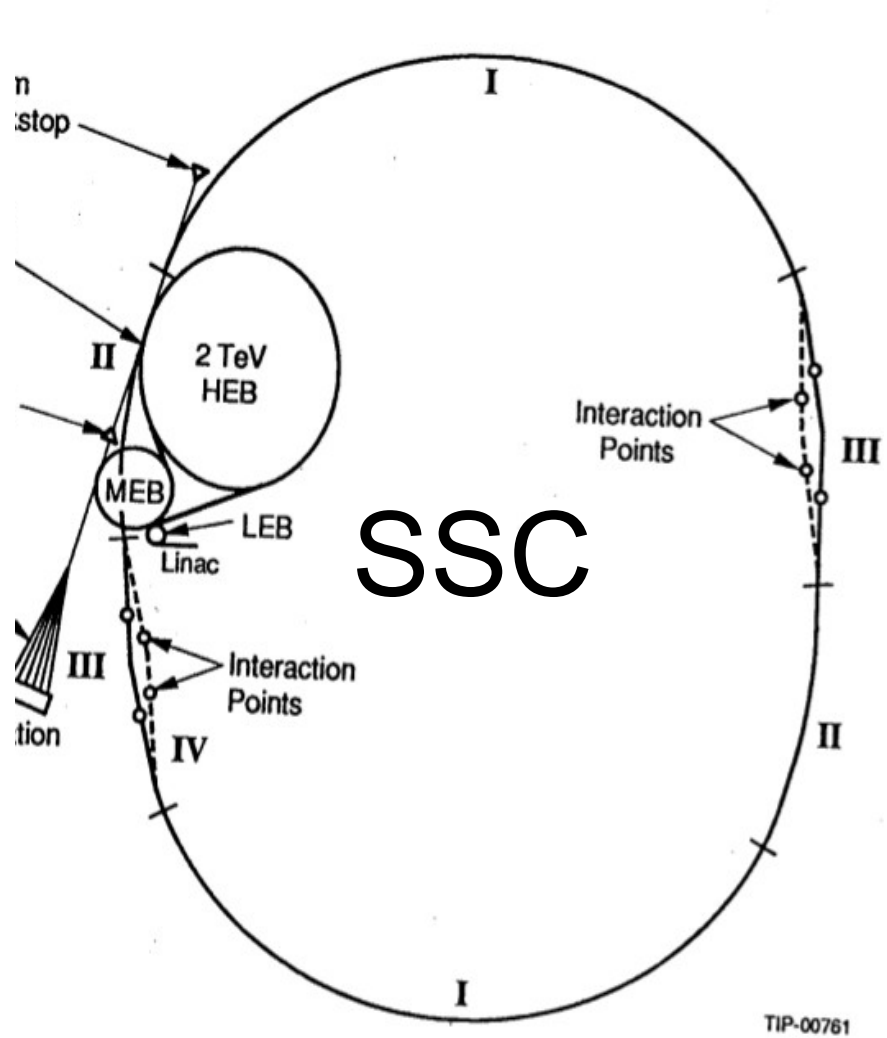
R. Tomas, M. Benedikt, L. Bottura, F. Cerutti, B. Harer, B. Holzer, E. Jensen, R. Martin, L. Medina, L.S. Esposito, D. Schulte, E. Todesco, J. Wenninger, S. White and F. Zimmermann

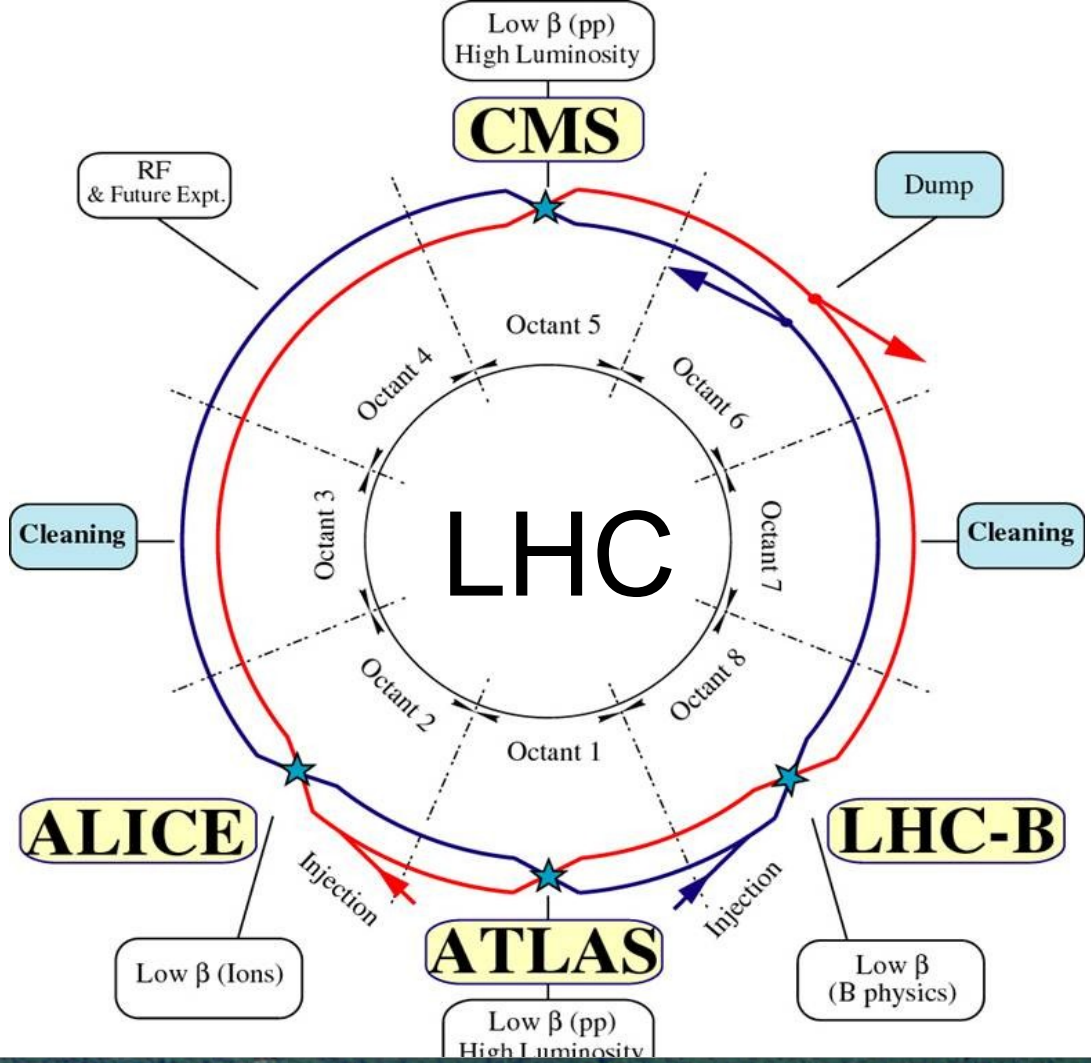
ICHEP 2014 VALENCIA
37th INTERNATIONAL CONFERENCE ON HIGH ENERGY PHYSICS
2-9-JULY-2014-VALENCIA

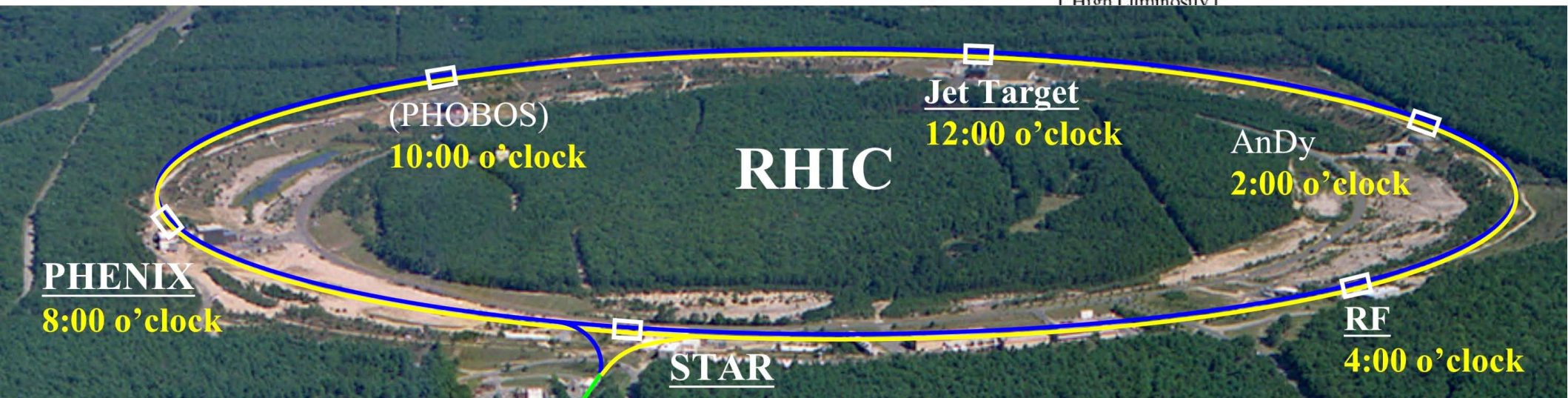
	FCC-hh	FCC-ee (TLEP)			
		Z	*W*	*H*	*top*
species	pp	e+e-	e+e-	e+e-	e+e-
E [GeV]	50000	45.5	80	120	175
Circ. [km]	**100**	**100**	**100**	**100**	**100**
bunches	10600	16700	4490	1360	98
ppb [10^{11}]	1.0	1.8	0.7	0.46	1.4
βx [m]	**1.1**	0.5	0.5	0.5	1
βy [mm]	**1100**	**1**	**1**	**1**	**1**
σx [μm]	6.8	121	26	22	45
σy [μm]	6.8	0.25	0.13	0.044	0.045

1. The tunnel


LHC
Jura
Lake Geneva
Prealps
Schematic of an
80 - 100 km
long tunnel
Salève
Aravis
Mandalaz
Copyright CERN 2014

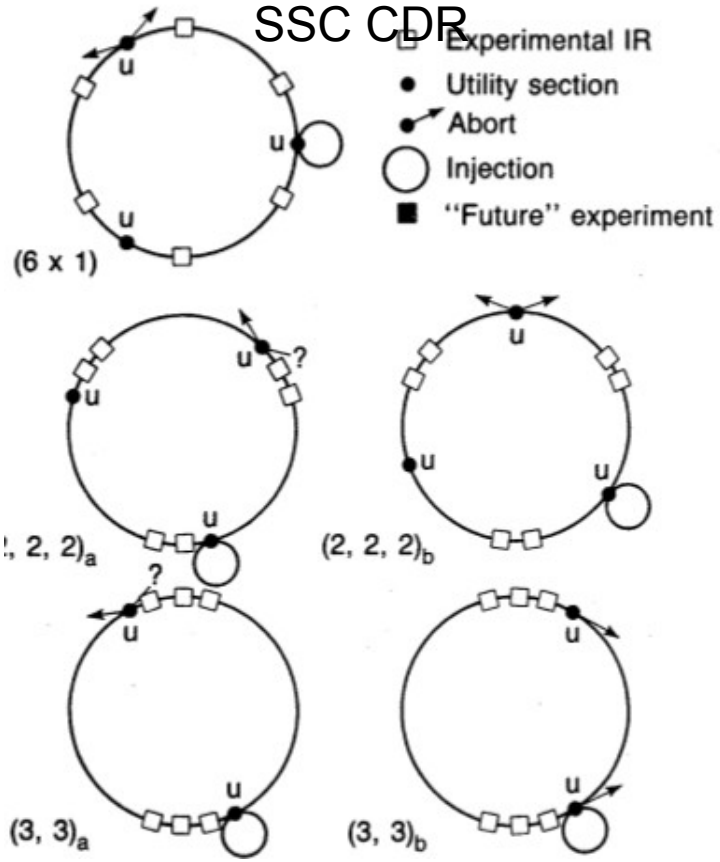

I
II
2 TeV
HEB
MEB
LEB
Linac
Interaction
Points
III
IV
II
I
SSC
TIP-00761


Low β (pp)
High Luminosity
CMS
RF
& Future Expt.
Dump
Octant 5
Octant 4
Octant 6
Octant 3
Octant 7
Octant 2
Octant 8
Octant 1
LHC
Cleaning
Cleaning
ALICE
LHC-B
Injection
Injection
ATLAS
Low β (Ions)
Low β
(B physics)
Low β (pp)


(PHOBOS)
10:00 o'clock
RHIC
Jet Target
12:00 o'clock
AnDy
2:00 o'clock
PHENIX
8:00 o'clock
RF
4:00 o'clock
STAR

Racetrack tunnel?

- SSC (racetrack) versus LHC/RHIC (circular)
- Clustered IRs versus evenly distributed



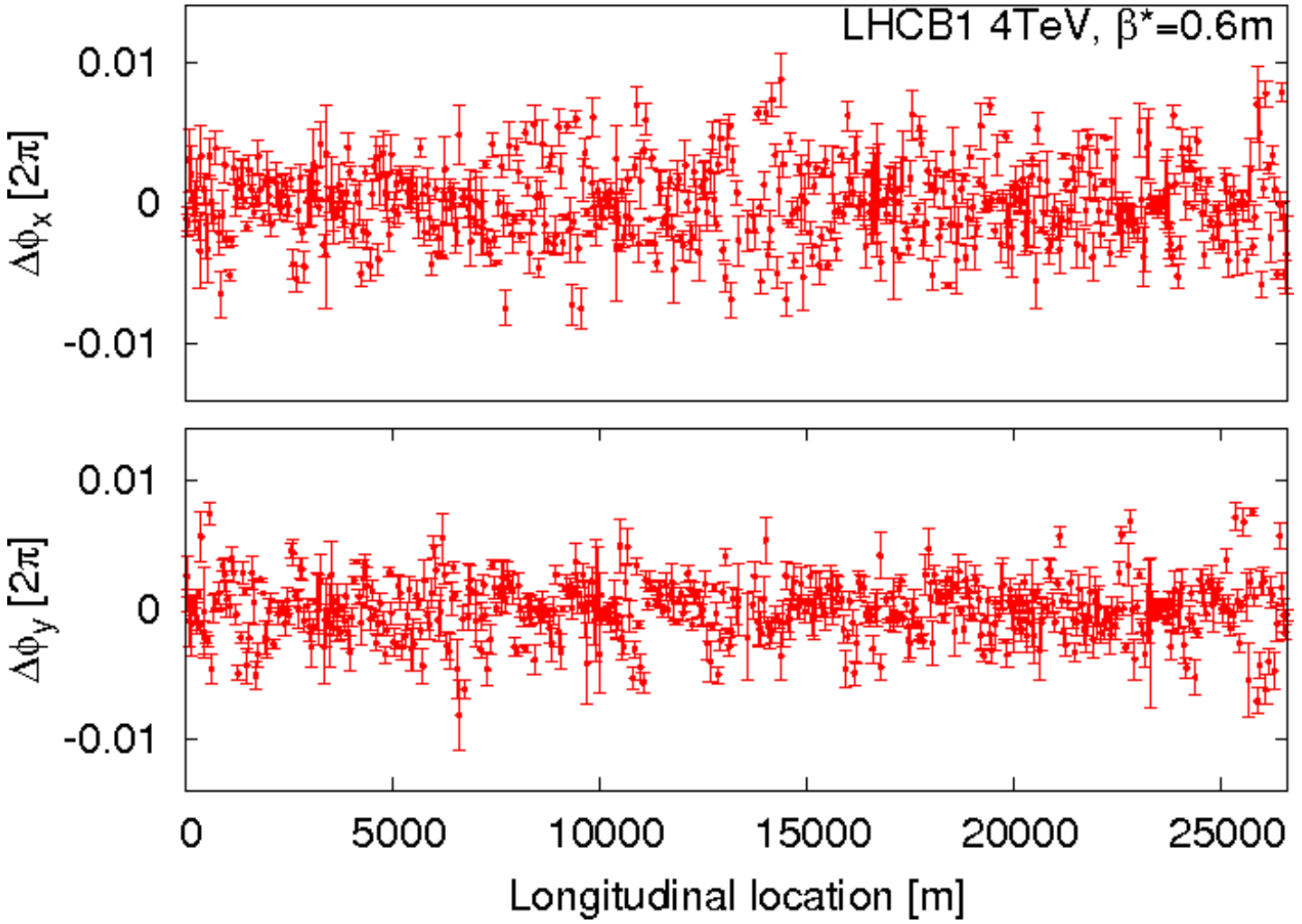
- Is this a strong argument?

There is a potential optical advantage of IR clustering. Compared with distributed IRs, clustered IR lattices have one more variable to control the optical quality, namely, the betatron phase advance μ between adjacent IPs in a cluster. The optimum value of μ is found to be an odd multiple of $\pi/2$ [4.2-7, -11, -12]. By pairing IRs in a cluster and setting μ to the optimum value, one minimizes the chromatic aberrations of particle motion. This optimum phase also helps to reduce the orbit effect from long-range beam-beam interactions and to suppress some of the incoherent beam-beam resonances.

To be more specific, the tune dependence on momentum is described to first order by the chromaticity. As mentioned, the chromaticity is set to zero by properly setting the two families of chromaticity sextupoles in the arcs. The second order dependence of the tune on momentum could be removed by introducing multiple sextupole families, but it is also substantially reduced if adjacent IRs are paired with $\mu = (2n+1)\pi/2$. Table 4.2-1 gives the tune deviation at $|\delta| = 10^{-3}$ for a few examples of test-lattice designs [4.2-10]. The adopted SSC lattice design has an IR clustering that is close to example 6 of Table 4.2-1, although the numerical values differ in detail. The value of μ is not listed for examples 1 and 2 since pairing does not apply. The condition of $\mu = (2n+1)\ \pi/2$ also minimizes the energy dependence of β^* and the beta function in the triplets, which in turn minimizes the spurious dispersion at the interaction point from misalignment of the IR quadrupoles [4.2-7].

The phase advance between clusters, accumulated through the long arcs, also has an

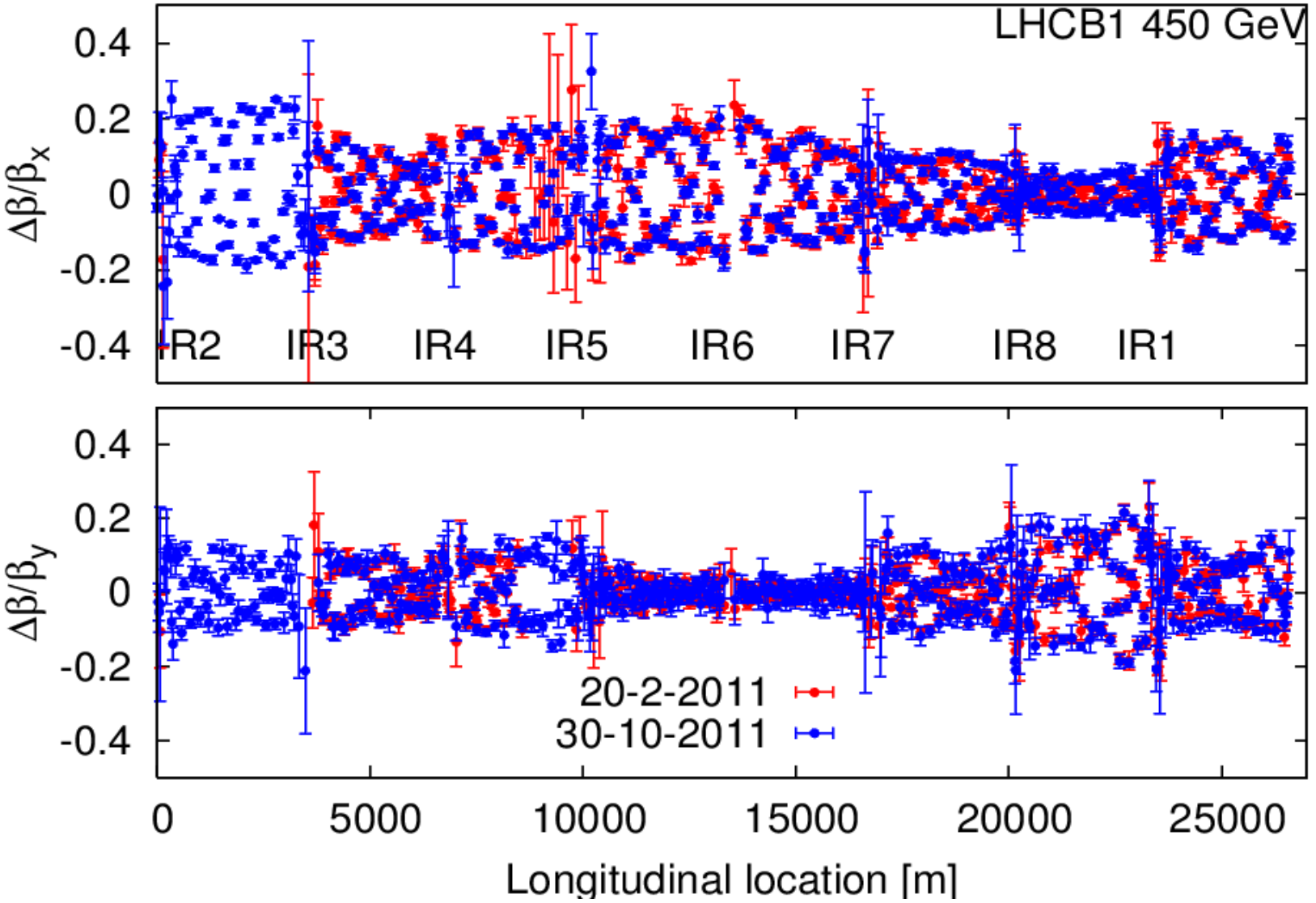
Optics control in the LHC



Few degrees error on the phase advance over 27 km.
Peak β-beating of 7%

R. Tomas et al, “Record low β-beating in the LHC” Phys. Rev. ST Accel. Beams 15, 091001

Rock stable optics over time



Tunnel shape

- For FCC-hh there are no strong arguments from beam dynamics in favor of any shape
- And for the FCC-ee machine?
  - Preliminary simulations with beamstrahlung and SR damping do not favor any option, but IR momentum bandwidth might make a difference.