

# Asynchronous free ATS optics for LHC & HL-LHC

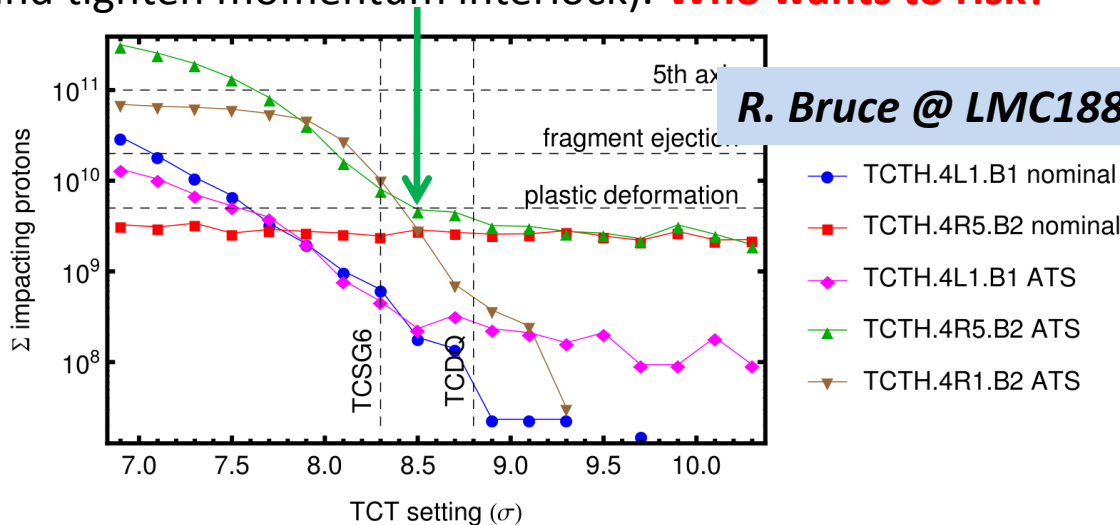
S. Fartoukh, BE-ABP

- Reminder: the “birthmark” of the current ATS (HL-LHC) optics
- Remedy
- Status & Plans for production and LHC implementation

# Reminder (1/2)

**$\sim\pi/2$  phase advance between MKD and TCT.IR5b2**

→ Clear MP issue for asynchronous dump (may be mitigable by opening the TCT and lose in  $\beta^*$  reach, and tighten momentum interlock). **Who wants to risk?**



**R. Bruce @ LMC188, 03/09/2014**

## LMC recommendation (in the context of using ATS optics for Run II)

**DECISION:** there is sufficient doubt not to restart with ATS optics in 2015, but its validation is sufficiently close that the LHC should be ready to move to the ATS optics, whenever it is ready.

**ACTION (for LSWG, LBOC):** the appropriate MD time/OP time for the validation studies of ATS compatible optics should be found in the schedule.

→ 64h ATS MD were requested by G. Arduini & M. Giovannozzi

(r)MPP recommendation (R. Bruce et al. @ LMC188), ... a fortiori valid for HL-LHC

→ A distance of at least  $\pm 40^\circ$  wrt  $90^\circ$  should be granted between MKD and TCTs (b1/2, IR1/5)

# Reminder (2/2)

## Phase advances for different (HL-)LHC optics versions:

- H phases from MKD to TCTs (Beam1/2, IR1/5) and H/V IP15 phases
- For the nominal LHC optics (Run I/II) these phases are changing (decreasing) with (low)  $\beta^*$ .
- For ATS pre-squeezed optics, these phases do no longer move below a certain transition  $\beta^*$

Phases[deg.] vs. Optics	Run I ( $\beta^* = 60$ cm)	Run II ( $\beta^* = 80/40$ cm)	ATS 2015 (pre-squeezed)	HL-LHC V1.2 (pre-squeezed)
B1H: MKD-TCT-IR1	58.479	56.652/36.546	119.736	116.665
B1H: MKD-TCT-IR5	50.038	52.231/28.105	148.216	152.527
B2H: MKD-TCT-IR1	-158.760	-171.911/147.831	101.701	110.059
B2H: MKD-TCT-IR5	174.861	-166.502/153.242	76.818	73.920
B1H: IP1 → IP5 IP5 → IP1	-8.441 120.041	-8.441 120.041	28.482 83.118	35.861 75.739
B2H: IP1 → IP5 IP5 → IP1	22.311 89.289	-5.410 117.009	28.758 82.842	36.139 75.461
B1V: IP1 → IP5 IP5 → IP1	-126.538 -118.262	-126.538 -118.262	-14.536 129.736	-19.037 134.237
B2V: IP1 → IP5 IP5 → IP1	-85.719 -159.081	-85.719 -159.081	-14.264 129.464	-18.763 133.963

→ Both nominal optics are very similar with all TCT's OK at 40 cm

(note the change of IP15 H phase for beam2, from Run I to Run II, due to IR4/8 optics changes)

→ Both ATS optics are very similar with all TCT's (but one) NOK, in particular

the most exposed TCT.R5b2

# Solution (1/4)

- $\Delta\mu$  (MKD  $\rightarrow$  TCT.R5b2)  $\sim 77^\circ$  (pre-squeezed)  $\rightarrow 90^\circ$  (telescopic)

**Option 1:** try to reduce this phase towards  $0^\circ$ , acting on the left side of IR6b2.

$\rightarrow$  Only a few degrees can be gained

**Option 2:** re-deploy an **ATS concept w/o  $\pi/2$  arc cell phase in the “strong” sectors s81/s12/s45/s56**

$\rightarrow$  Possible but a nightmare in terms of complexity (kind of mixture between “Phase-I-like” and ATS optics).

**Option 3:** try to increase this phase towards  $180^\circ$ , acting on the left side of IR6b2.

$\rightarrow$  .. and revive the very old (qualitative) picture of the “Verdier IR6 Potatoes”.

# Solution (2/4)

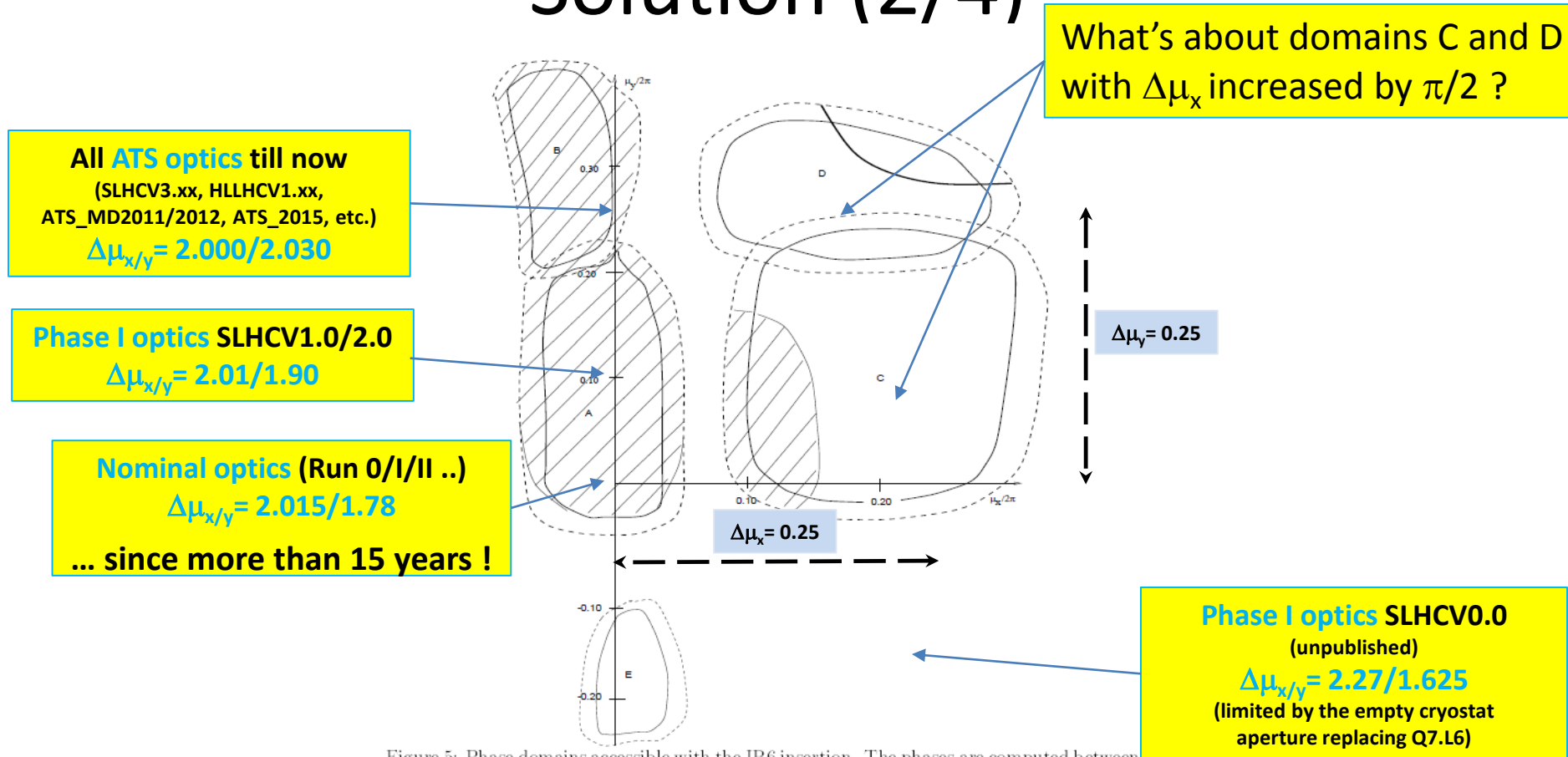


Figure 5: Phase domains accessible with the IR6 insertion. The phases are computed between the end of QF15.L6 upstream and the beginning of QD13.R6 downstream, for the 63.59 optics. The closed curves limit the tune changes (the phase of the insertion for the 63.59 optics is taken as origin) accessible by the matching routine from any point inside the curve. The hatched areas correspond to a limitation of the Q8 trim gradient to the integrated value of  $1.7 \times 0.00514 \text{ m}^{-1}$ . The other trim quadrupoles do not introduce any limitation under this condition except for diagram D where the thick line gives the lower limits of the phases accessible with the limitation of the gradient of Q7.L6.

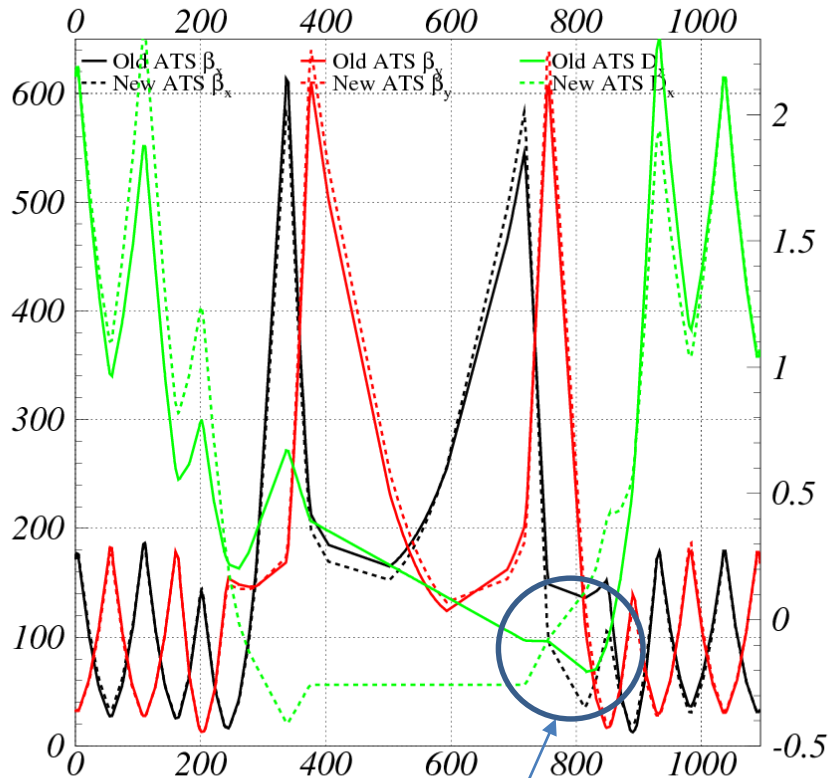
## IR6 tuneability diagram (for old LHC-DS Layout)

A. Verdier @ LHC-Project-Note 146 (1998)

→ The different "potatoes" are **disconnected** (i.e. the optics constraints should be relaxed to pass from one to the other due to the missing Q6 and Q7)

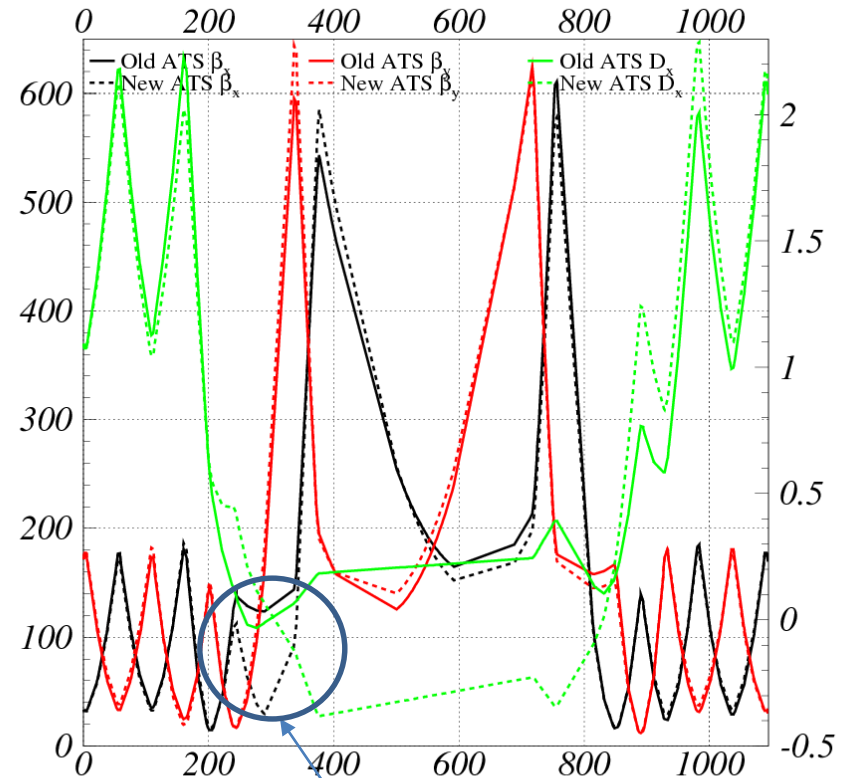
# Solution (3/4)

## Beam1



The  $+\pi/2$  H-phase shift is Confined on the right

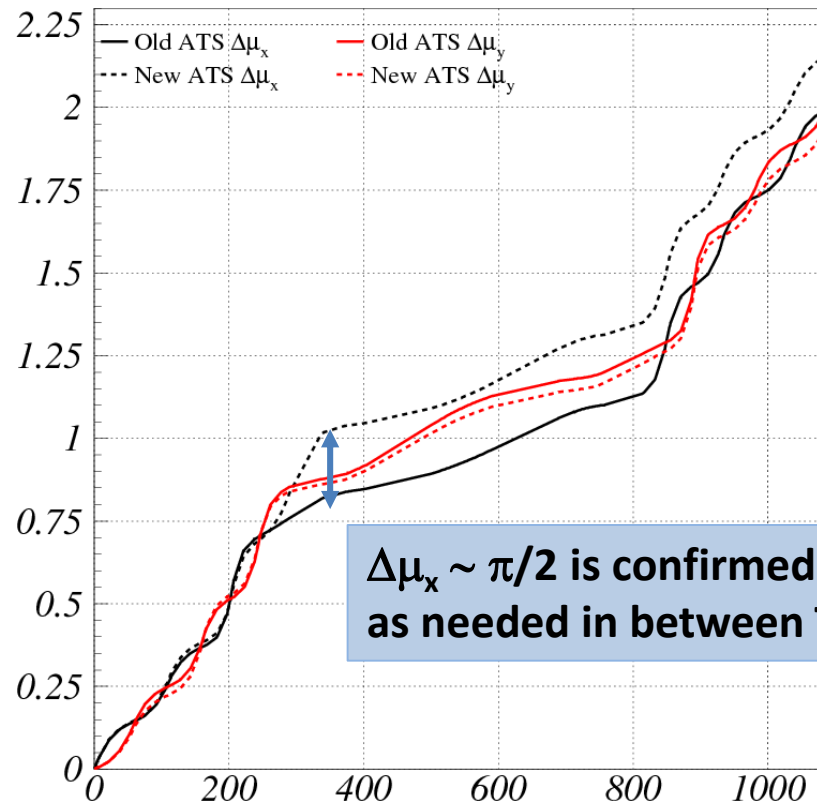
## Beam2



The  $+\pi/2$  H-phase shift is confined on the **left**

# Solution (3/4)

## Beam2 phase [ $2\pi$ ] along IR6: new vs. old



$\Delta\mu_x \sim \pi/2$  is confirmed on the left side of IP6 as needed in between TCT.R5b2 and MKD !..

# Solution (4/4)

**Phase advances for new ATS versions compared to nominal (Run I/II):**

**V1:** tunes re-matched with the “weak” sectors (same QF/QD in s23/34/67/78), as proposed for the 3<sup>rd</sup> MD block, but **leading to IP15 phases close to 0 in both planes for both beams**

**V2:** starting from V1, **the IP15 phases of Run I are reproduced** (different QF/D in s23/34/67/78 and non zero nominal RQTF/D in s23/34/67/78)

Phases[deg.] vs. Optics	Run I ( $\beta^* = 60$ cm)	Run II ( $\beta^* = 80/40$ cm)	ATS new V1 (pre-squeezed)	ATS new V2 (pre-squeezed)
B1H: MKD-TCT-IR1	58.479	56.652/36.546	164.546	171.729
B1H: MKD-TCT-IR5	50.038	52.231/28.105	164.228	163.289
B2H: MKD-TCT-IR1	-158.760	-171.911/147.831	148.759	171.604
B2H: MKD-TCT-IR5	174.861	-166.502/153.242	148.801	149.293
B1H: IP1 → IP5 IP5 → IP1	<u>-8.441</u> <u>120.041</u>	-8.441 120.041	-0.317 111.917	<u>-8.441</u> <u>120.041</u>
B2H: IP1 → IP5 IP5 → IP1	<u>22.311</u> <u>89.289</u>	-5.410 117.009	-0.0427 111.643	<u>22.311</u> <u>89.289</u>
B1V: IP1 → IP5 IP5 → IP1	<u>-126.538</u> <u>-118.262</u>	-126.538 -118.262	-5.536 120.736	<u>-126.538</u> <u>-118.262</u>
B2V: IP1 → IP5 IP5 → IP1	<u>-85.719</u> <u>-159.081</u>	-85.719 -159.081	-5.264 120.464	<u>-85.719</u> <u>-159.081</u>

# Status and Plans

## for production & implementation

- Telescopic squeeze to be re-done/re-checked for V2
  - Slight degradation of the phases expected w.r.t. presqueeze (<10 degrees)
- Otherwise, injection, ramp and pre-squeeze

“virtually” ready for MD

- i.e. injection optics and pre-squeezed sequence to be assembled, with knobs (IP, Q, Q', coupling, spools) and chromatic correction
- Aperture at injection may be to be re-checked/re-optimize in detail
- Thin lens version to be done to check loss map

first on paper (DA will be checked in MD with Q', MO, etc..)

- MD series to be prepared, posted and done before implementation in LHC.
- Long term development to be discussed (flat, high  $\beta^*$ , high MO efficiency arc optics, ...).