A possible roadmap for HL & WP2 (re-)synchronization

FOR DISCUSSION

- From the HHH vision, to Phase-I, to the HL-LHC with ATS **in terms of optics** & **triplet aperture**
- The **ATS**: a quick risk analysis
- **Urgent tasks for decision making** in the next few months
- Beam and optics parameters … to start with
- The **task leaders** take the floor:
  - set of sub-tasks with **clearly defined deliverables and delivery dates**
  - named responsible(s) for each sub-task, with FTE counting
  - specification of the information and tools required to perform each sub-task.

A bit of history in terms of optics

- **The HHH vision** (an over-simplified description)

1) The only limit is the triplet aperture:

$\boldsymbol{\beta^* \propto 1/(Aperture)^2/(Gradient)^{1/2} \propto 1/(Aperture)^{3/2}}$ **→ 0 at large aperture.**

- **Phase I**

1) Other limits from the ring (IR quad & sext. strength) to be added:

$\boldsymbol{\beta^* \propto 1/\,(Gradient)^{1/2} \propto (Aperture)^{1/2}}$ **→ +∞ at large aperture.**

2) An optimal IT aperture (not technology dependent) can be found:

120 mm for the LHC → β^*~ 30/24 cm for NbTi/Nb3Sn with 0 margin (some margin can be restored by moving the MS, push the sext. up to 600 A,..)

- **The ATS**

1) Restores the HHH vision: "no β^* limit" (assuming enough IT aperture)
2) ….but introduces new kind of possible limitations (see next slides)

The ATS: a quick risk analysis (1/2)

- Possible operational complications/limitations/show-stopper

- **Modification of the IR4/IR6 optics during the squeeze** → study on-going with ATS MD, links established with WP7 (machine protection) & WP13 (Beam diagnostics).

- **Partially eats the squeeze-ability of IR2 and IR8** → **task 2.2** (analyze and eventually re-optimize the IR2/IR8 phase to restore a decent squeeze-ability)

- **Dynamic aperture already degraded with arc imperfections only** → **task 2.3 & 2.5** (include in tracking a first IT error table based on simple scaling of the existing MQX, include beam-beam in tracking, address the topic in a new series of ATS MDs)

- **Change of β's in DS of IR1 and IR5** → **links between 2.2 and WP5** (IR collimation)

- **IBS reduction in the H plane** (improvement in Z-plane) → **task 2.4**

- **Any other bad surprises??**

The ATS: a quick risk analysis (2/2)

- Risk v.s. Potential gain

1) Case 1: The ATS works

→ Decide 140-150 mm IT and **gain 60 up to 80% in β^*** (as low as 13-15 cm or lower?) w.r.t. Phase I optics scheme and 120 mm Nb3Sn IT

2) Case 2: The ATS does not work (or only partially)

a) Show-stopper identified before the decision on IT aperture

→ Decide 120 mm with the Phase I optics scheme (ready for NbTi, easier with Nb3Sn)

b) Show-stopper not identified before the decision on IT aperture

What if an un-optimized 140-150 mm IT (150-135 T/m) instead of 120 mm (170 T/m)?

→ **Too long/weak triplet** but big aperture margin for any eventual further development and less stringent FQ requirements

→ **Useless complication with the new matching section** (no longer needed)

→ Loss of β^* by 6% (if 140 mm) to 12% (if 150 mm) w.r.t. 120 mm

….. My conclusion: We should focus our effort on 140 mm and decide together with WP3 in a couple of months to even go to 150 mm (if possible??).

…..The risk for β^* (not for cost) is indeed minimal (like sqrt(Aperture)) while the gain is very attractive (like $1/(\text{Aperture})^{3/2}$).

Urgent tasks (within the next few months)

1. **First layout and ATS collision optics to feed all WP2 tasks: DONE**

→ **SLHCV3.01** providing slightly pessimistic (i.e. conservative) optics conditions for any kind of study ($\beta_{arc} \times 4$ for β^*=15 cm, β_{max} =22 km for β^*=15 cm @ 120 T/m)

2. **More optimized layout and ATS collision optics to feed WP3-10: Nearly DONE**

→ **SLHCV3.1b** providing optimized optics conditions ($\beta_{arc} \times 2.6$ for β^*=15 cm, β_{max} =20 km for β^*=15 cm @ 150 T/m)

3. **First IT/D1 error table in collision to be prepared and tracked with SLHCV3.01 @ β^*=15 cm → Task 2.3 (YC, MG, RDM, SF, ??)**

4. **Idem with HO and LR beam-beam effects → Task 2.5 (MG, RDM, YC, SW, ??)**

5. **Squeeze-ability of IR2/IR8** for all collision optics configurations provided in SLHCV3.1b (i.e. with different peak β's in the arcs). If necessary, re-optimize the phases of IR2/IR8 to restore a decent situation → **Task 2.2 (BH, ??)**

6. **IBS calculations** for all optics configurations of SLHCV3.1b → **Task 2.4** (**EM**,**??**)

7. **DS collimator with ATS optics** (if necessary, perform a first study using ATS_V6.503 to speed up the setting up) → **WP5 in collaboration with Task 2.2 (RA,SR, BH,??)**

Beam parameters (from Oliver)

"HL-LHC Kick off +"	25 ns	50 ns
# Bunches	2808	1404
p/bunch [10^{11}]	2.0	3.3
ε_L [eV.s]	2.5	2.5
σ_z [cm]	7.5	7.5
$\sigma_{\delta p/p}$ [10^{-3}]	0.1	0.1
$\gamma\varepsilon_{x,y}$ [μm]	2.5	3.0

N.B: In case of limitation with large Piwinsky angle (synchro-betatron resonnances), we may want to establish a parameter list with shorter bunch length (e.g. 4cm), in collaboration with the RF group (800 MHZ cavities), Task 2.5 (IBS, coherent tune shift) & Task 2.6 (performance re-optimization)

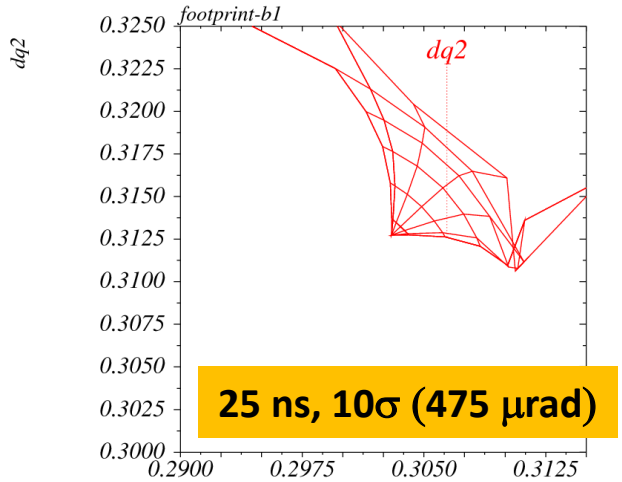
Optics parameters (preliminary)

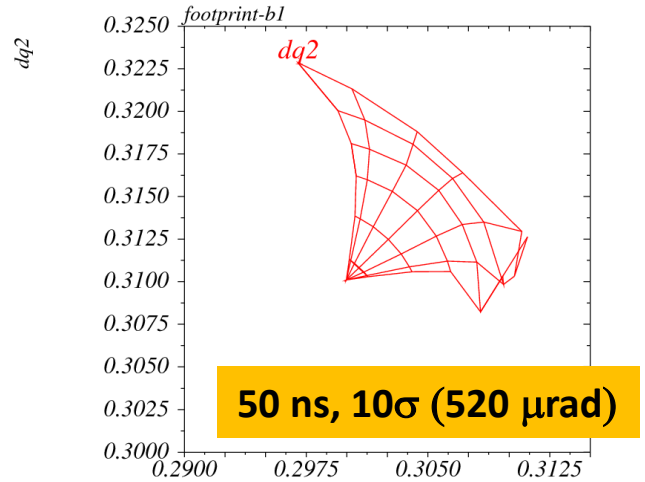
Optics parameters	"nominal-HL"	"Back-up"	"Ultimate-HL"
Injection @ 450 GeV			
β^* [m]	5.5	11	5.5
Half-Xangle [μrad]	245	170	245
Half-parallel sep [mm]	2	2	2
Collision round @ 7 TeV (X-angle set to 12σ at 2.5 μm emittance)			
β^* [m]	0.15	0.25	0.10
Half-Xangle [μrad]	290	225	350
Collision flat @ 7 TeV (crossing in the plane of biggest β^*, set to 15.5 σ at 2.5 μm emittance)			
β^* [m]	0.30/0.075	0.25/0.25	0.20/0.05
Half-Xangle [μrad]	265	225	325

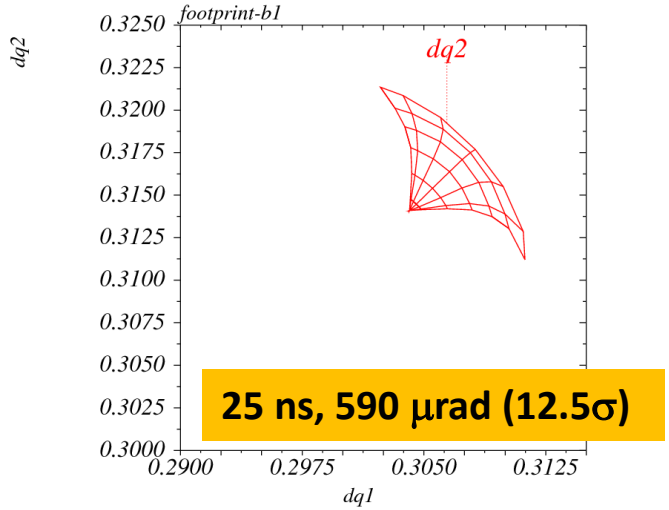
→ Most of these optics are available in SLHCV3.01 (120 T/m IT): the "Ultimate-HL" are missing
→ All these optics (but the Phase I-back-up @ 25 cm) will be shortly available in SLHCV3.1b (150 T/m IT)

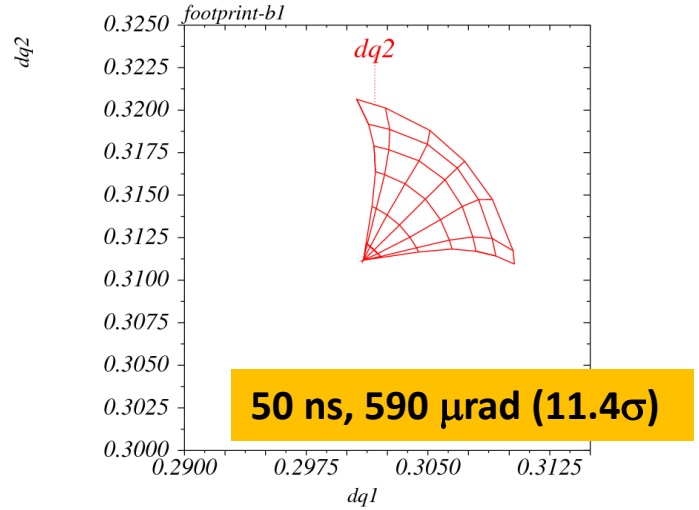
Why a priori 580 μrad Xangle and not the "canonical" 10σ of "HL-LHC Kick off +"?

→ **Tune footprint at 6σ** with **21 LR's per IP side (longer IT)**, HO at IP1 and IP5, β*=15 cm and **beam parameters (higher bunch charge)** given in the previous table



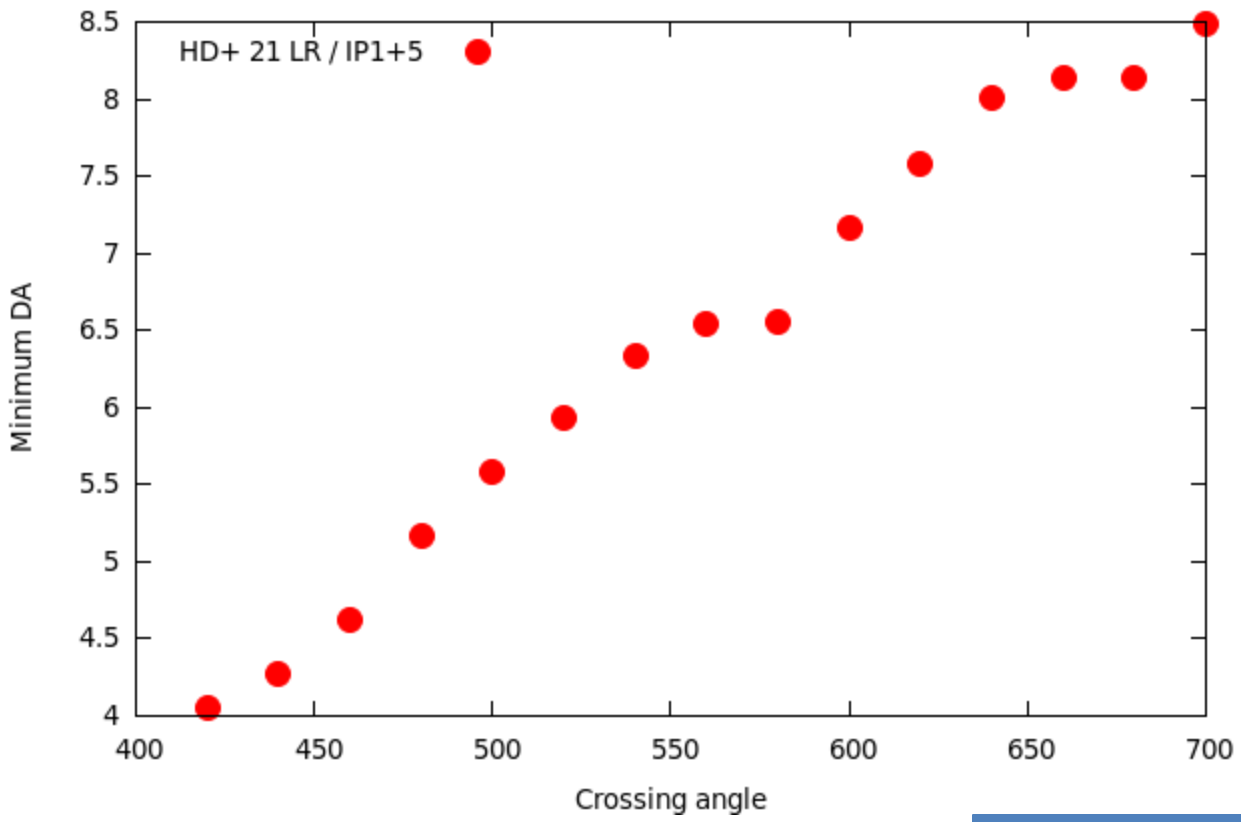






→ 100’000 turns DA simulation results vs Xangle confirming “pathological tune footprint” (using SLHCV3.01)

(25 ns beam parameters, β*=15 cm, only sextupoles, LR and HO, no crab-crossing no field imperfection)



Courtesy of S. White

The floor is given to the task-leaders!

The aim is

1. to collect the list of sub-tasks, expected deliverables & participants (name,FTE)

2. to check **rapidly** whether the effort of each lab. is equal or larger than the grant agreement.

3. to identify area of strength and relative weakness, possible synergies or inconsistencies and duplications across tasks, and eventually missing sub-tasks

4. **Establish together** the WP2 work flow, including FTE, deadlines and deliverables

This is the start of an iterative process which might take 2 or 3 task leader meetings before compiling/checking all the information and **agreeing on the route towards the HL-LHC.**