HL-LHC V1.6 Status

R. De Maria for WP2

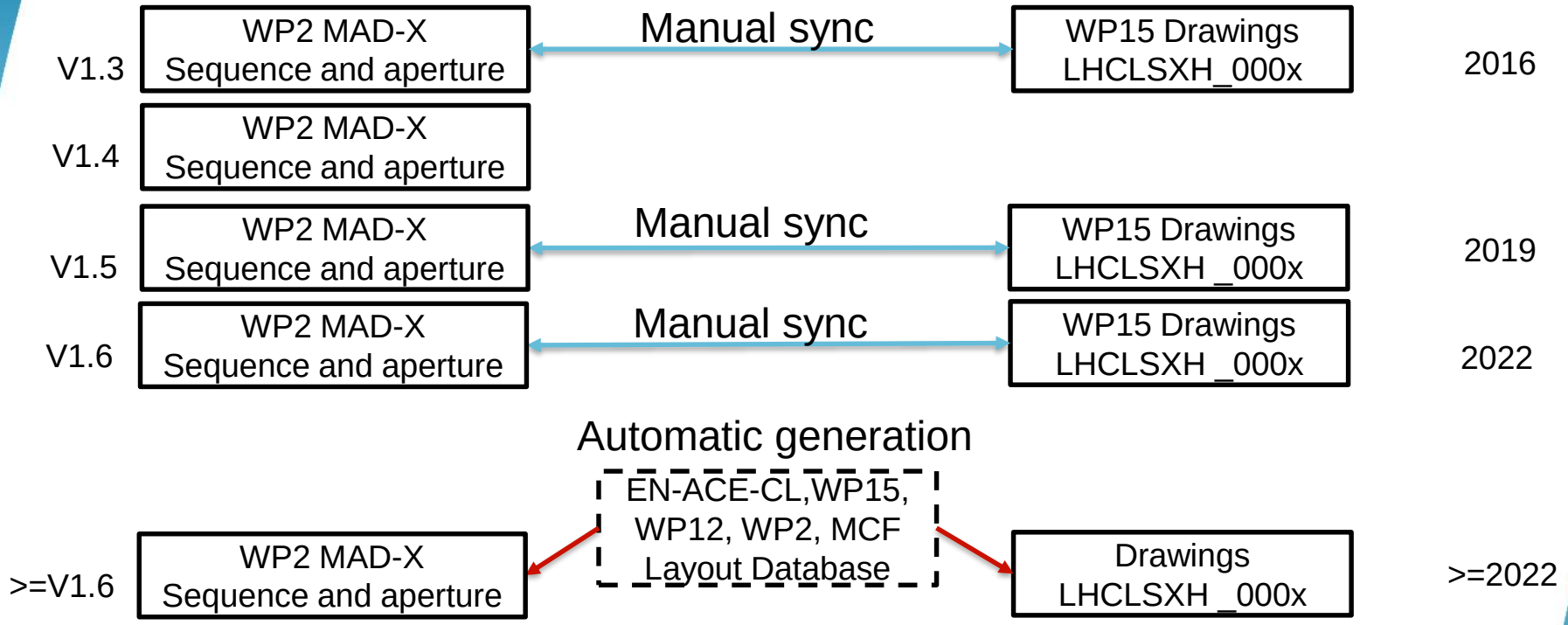
Thanks to all work-packages and in particular WP15 P. Fessia, G. Cantalapiedra and J. Oliveira for the excellent support!

Thanks for setting up the zoom connection and allow me to reduce the carbon footprint of my talk!

Layout changes V1.5->V.16

- Refined triplet magnetic length (~cm longer at constant integrate length) and position (thermal contraction)
- Refined CP positions (better rounding)
- Name change (BPM, CRABS ACFGA->ACFCA)
- Change length TAXN (3.332 m ->3.310 m)
- Change name and position of CRAB, APWL and BPTX (name only)
- Changed position TCT/L.5/6, TCLMB/C
- MS 10 not in drawings, but perhaps could be reinserted
- No MBH

Layout/Optics References



Circuit and aperture data work in progress,
WP15 to pass responsibility to EN-ACE-CL

Run 4 e-cloud mitigation scenarios

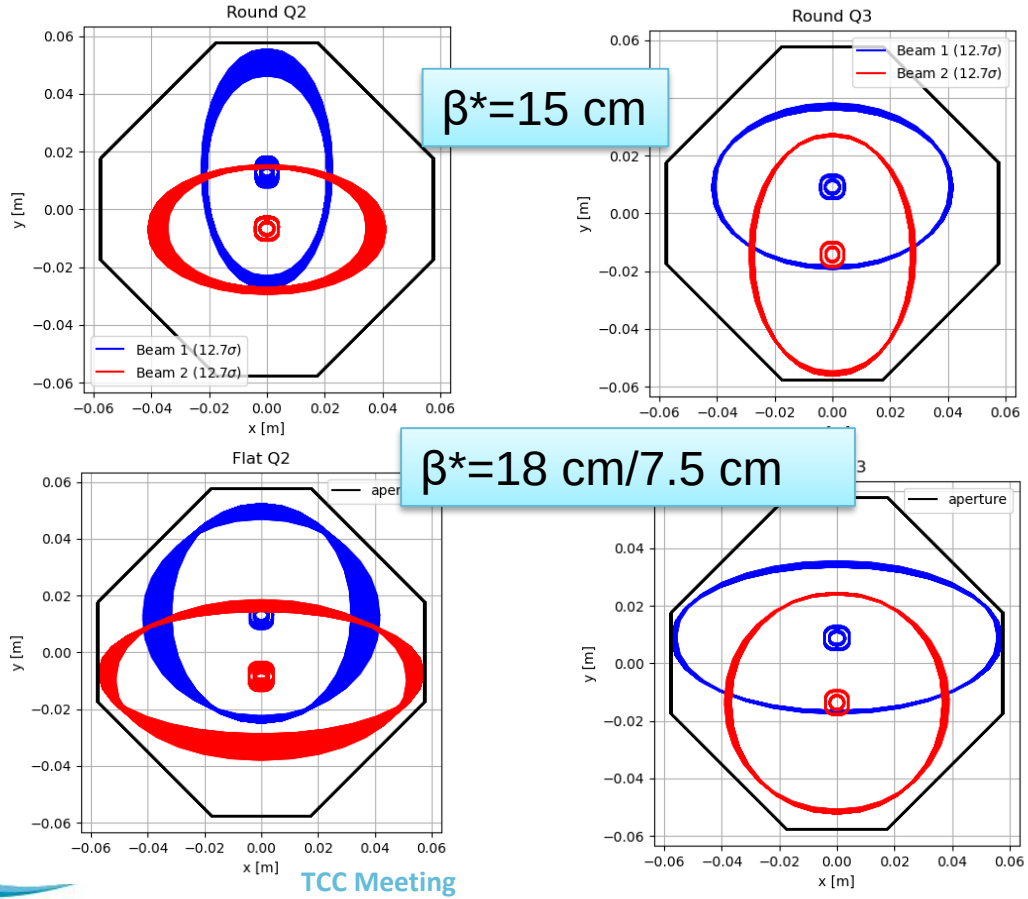
e-cloud in arc78 limiting # of bunches to, e.g., 2200 ($L_{lev.}$ = 5×10^{34}cm^{-2}/s)

# of bunches	$\beta^*_{x,y}$ [cm]	L_{int} [fb^{-1}]	ppb $[10^{11}]^{end}$	Pile-up	Fill length [h]	Hardware / comment
2748	20, 20	242	1.40-1.18	131	7.3	baseline Run 4
2200	20, 20	215	1.60-1.27	164	5.6	Lifetime!?
2200	15, 15	226	1.43-1.17	164	6.1	+MS10
2200	18, 9	234	1.30-1.09	164	6.6	+MS10
2200	18, 7.5	237	1.26-1.05	164	6.6	+MS10+2CuCD

Ultimate scenario limited to **$L_{lev.}$ = 6.1×10^{34}cm^{-2}/s** brings little gain (at most 261 fb^{-1}). Need to support Heat Load Task Force work to prepare surface treatments techniques and optics alternatives: Flat, MS10, CuCD, wire.

- Important to aim at β*=18/7.5 cm to mitigate risks.
- β* at the beginning of levelling depends on the operational scenarios and collimator settings.
- Detailed optics choices cannot be fully resolved

Aperture at different beta*



Vertical crossing in Point 5 requested for CMS forward physics program

Flat optics makes better use of the aperture, but pushes the bottleneck in the horizontal plane, requiring the tightest TCT settings.

Optics constraints do not allow to optimize the MKD – TCT phase advance as well as in round optics

Optics configurations

β* m (h/v)	IP1	IP5	IP2	IP8	Comments
Round	0.15	0.15	10	1.5	
FlatCC HV	0.18/0.09	0.09/0.18	10	1.5	(more difficult to keep the phase see later)
FlatCC VH	0.075/0.18	0.18/0.075	10	1.5	
Flat HV	0.30/0.075	0.075/0.30	10	1.5	
Flat VH	0.075/0.30	0.30/0.075	10	1.5	
Optics in progress to follow operational scenarios studies					
Ion	0.5	0.5	0.5	1.5	Could change
EoRamp Round	1	1	10	1.5	Tentative, with anti-level?
EoRamp Flat	0.5/2	2/0.5	10	1.5	Tentative, with anti-level, low beta crab?
Injection	6	6	10	10	
VDM	30	30	30	30	No official high-beta request

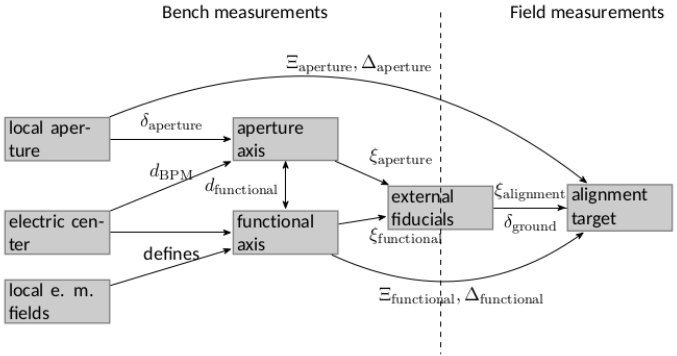
Optics, aperture, crossing plane

	Round	Flat VH	Flat CC VH	Flat CC HV	Flat CC HV
β* Xing/Sep [cm]	15/15	30/7.5	18/7.5	18/9	18/7.5
Xing angle [μrad]	±250	±245	±240	±240	±240
Crossing plane IP5	V	H	H	V	V
Worst-case aperture Xing plane [σ]	13.1	15.6	14.2	14.2	14.2
Worst-case aperture Sep plane [σ]	16.5	12.7	12.7	13.9	12.7
MKD-TCT [°] IP1 [B1/B2]	5/19	23/10	4/6	13/22	8/22
MKD-TCT [°] IP5 [B1/B2]	30/31	14/22	27/25	40/45	51/54
H Ap. Protected IP1 W/Cu	11.2/11.2	11.4/11.2	11.2/11.2	11.3/11.2	11.3/11.2
H Ap. Protected IP5 W/Cu	11.9/11.2	11.3/11.2	11.7/11.2	13.3/12.3	14.1/13.1
Ap. Margin Tight settings [σ]	1.9	1.3	1.5	0.6	-1.4
Ap. Margin Relaxed settings [σ]	0.9	0.3	0.5	-0.4	-2.4

Assuming different settings for TCTH and TCTV and tight collimator settings (R. Bruce).
Tight settings needed to exploit flat optics with HV crossing (preferred by CMS)

New tolerance model

- Work in progress based on LHC-G-ES-0023



Quantity	Components
Align the aperture reference axis	
Aperture deviation	$\Delta_{\text{aperture}} = \delta_{\text{aperture}} + \xi_{\text{aperture}} + \xi_{\text{alignment}} + \delta_{\text{ground}}$
Functional deviation	$\Delta_{\text{functional}} = d_{\text{functional}} + \Delta_{\text{aperture}} - \delta_{\text{aperture}}$
Align the functional reference axis	
Functional deviation	$\Delta_{\text{functional}} = \xi_{\text{functional}} + \xi_{\text{alignment}} + \delta_{\text{ground}}$
Aperture deviation	$\Delta_{\text{aperture}} = d_{\text{functional}} + \Delta_{\text{functional}} + \delta_{\text{aperture}}$
Alignment follows another equipment	
Aperture deviation	$\Delta_{\text{aperture}} = \Delta_{\text{aperture,leader}} + d_{\text{BPM}}$
Field deviation	$d_{\text{functional}} = d_{\text{functional,leader}} + d_{\text{BPM}}$
All cases	
Aperture uncertainty	$\Xi_{\text{aperture}} = \delta_{\text{aperture}} + \xi_{\text{aperture}} + \xi_{\text{alignment}}$
Functional uncertainty	$\Xi_{\text{functional}} = \xi_{\text{functional}} + \xi_{\text{alignment}}$

Refined aperture values, and new tolerances values.

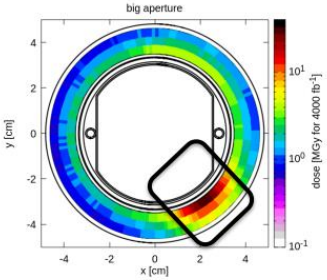
Allow new statistical approach ($\sqrt{\sum c_i^2}$) instead of the worst-case scenario ($\sum |c_i|$)

Required separate discussion for implication on β* reach.

New version of LHC-G-ES-0023 in preparation.

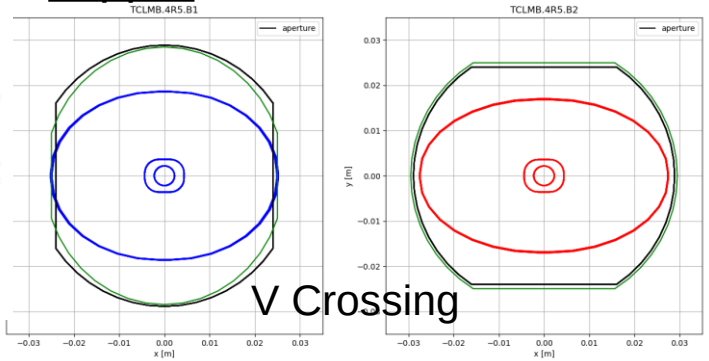
TCLMB Shape optimization

Inermet+ copper



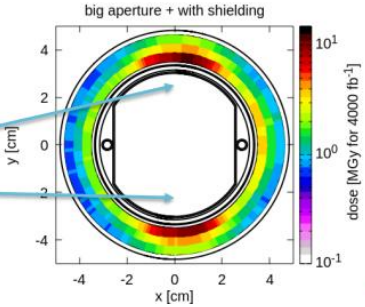
F. Cerutti,
M. Gilarte

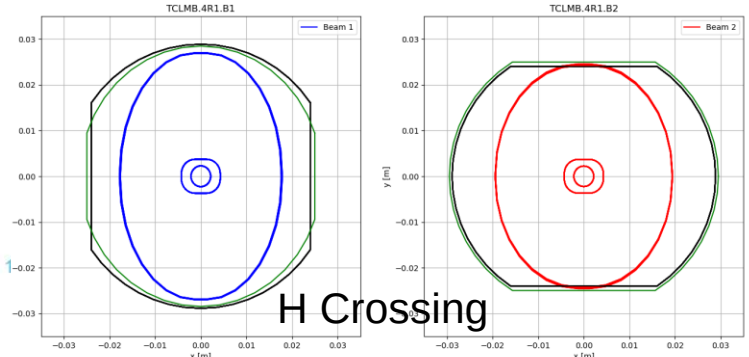
Copper



V Crossing

Beam envelope 14.2 sigma





H Crossing

Beam 1 Beam 2

Present shape for both Inermet and copper:
Round gap = 60.2+-1mm
Flat gap = 50.6+-1mm

Proposed shape

Inermet+copper
Round gap = 58/54 (H,V)+-1mm (+)
Flat gap = 51+-1mm

Copper_only
Round gap = 60+-1mm (*)
Flat gap = 51+-1mm

Gain:
- 2 mm of additional protection
- 0.8 sigma increase of aperture thanks to an increase of the not exposed aperture

WP2 Repository status

Differently from previous versions HLLHCV1.6 is stored in the acc-models-lhc repository (gitlab, afs, eos) showly preparaing for operations!

Sequence:

1. As for 1.5: lhc.seq (Run 3) + hllhc_sequence.madx (modification)
2. Generated from LDB: lhc_hl16.seq (not usable yet):
   - Missing circuits

Optics files: work in progress (15 cm optics available)

Aperture: work in progress. Tolerances will be based on new tolerance model LHC-G-ES-0023, to be discussed at another meeting.

Conclusion and next steps

- HL1.6 repository still in progress.
- Next steps:
  - Continue validation of layout DB data.
  - Completion aperture model and consequences on beta* reach.
  - Study new configuration for end of ramp and connection with injection.

Back-up