Tracking simulations of beam losses in the HL-LHC triplet

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Introduction

- Past work by M.Sapinski et al. about setting BLM thresholds at the IT for Nominal LHC (see kick off meeting, 2016-12-05 – indico page):
  - it is difficult to set a unique threshold for all IT BLMs able to identify the onset of slow losses;
  - Competitiveness between signal from debris and signal from losses:
    - the debris signal has time to pile up and set a high background level for the signal due to the slow losses;
    - The quench limit sets an upper limit to the loss rate, and thus to the signal induced by the loss;
  - For the luminosity upgrade of the LHC, cryoBLMs (i.e. cold BLMs in the proximity of/inside the cold mass) could be installed:
    - Expected to have a better response to energy deposition in the SC coils than present BLMs, due to their more favorable position;
  - Outcome based on numerical simulations, i.e. tracking with SixTrack (definition of losses at IT) and Fluka (endep in SC coils and BLMs);
- Past results were for Nominal LHC / LHC Phase I Upgrade: let's update figures for HLLHC:
  - R.Bruce proposed four possible scenarios of losses in the IT:
    - High losses in standard operation → IT sees the usual halo from TCTs;
    - High losses with misaligned TCT → IT sees halo from IR7;
    - Orbit bump → IT sees halo from IR7;
    - Triplet fully exposed during MD / commissioning → IT directly sees beam halo;

In presence of collisions

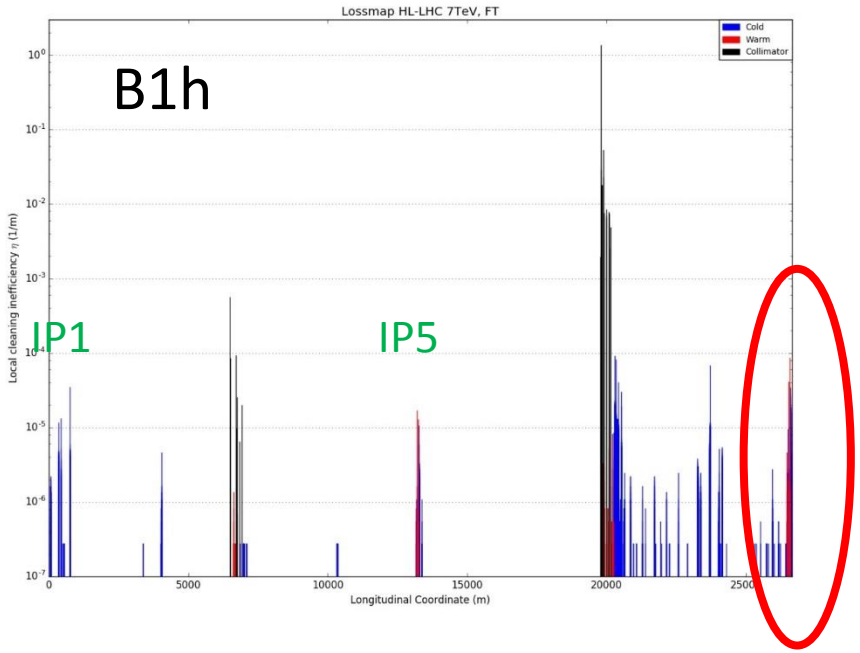
Simulation configuration

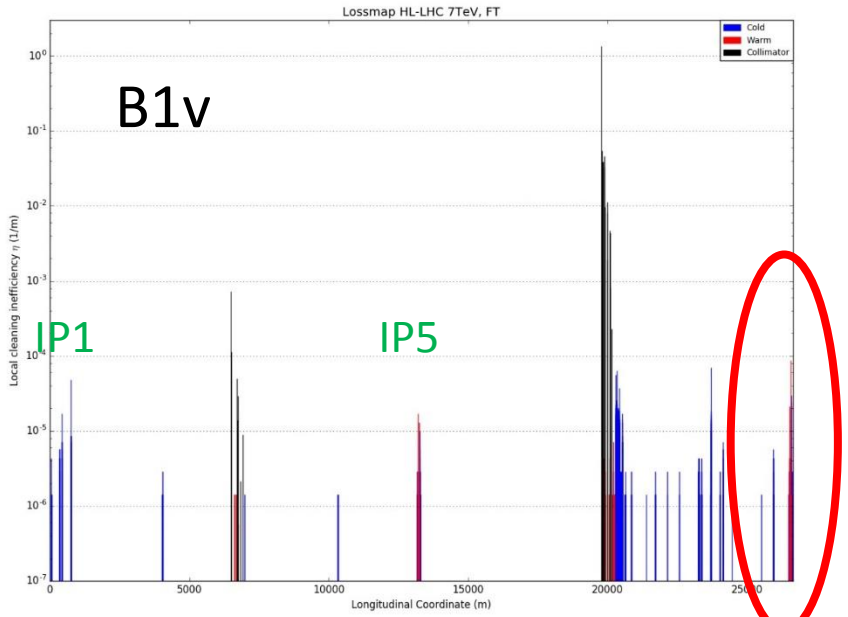
- Loss case: IT partially sees IR7 halo due to misaligned TCTs → let's fully open the TCTs (conservative);
- Energy = 7.0 TeV, β^* = 15 cm, with *parallel separation on* (no actual collisions);
- Open TCTs in IR1/2/5/8 → aim: to simulate *missing protection* from TCTs;
- Open TCLAs in IR7 and collimators in IR6 (TCDQ/TCSG) in IR6 → aim: to *increase losses in IT*;
- TCLs are open (parallel separation on);
- Usual cases of halo cleaning: B1h, B1v, B2h, B2v, for HLLHC optics v1.2 – regular crossing angle 295 µrad;
- For scenario with highest losses in IT, a case with crossing angle increased by 100 µrad was run as well, to quickly check increase of losses with larger crossing angle;
- Standard betatron halo sampled as for regular cleaning simulations → but increased statistics for having meaningful results at the IT!
- Even with these assumptions it was hardly possible to see some losses in the IT, but managed to collect enough statistics!
- The octagon BS in the IT was approximated to a squared BS – due to technical / time reasons…

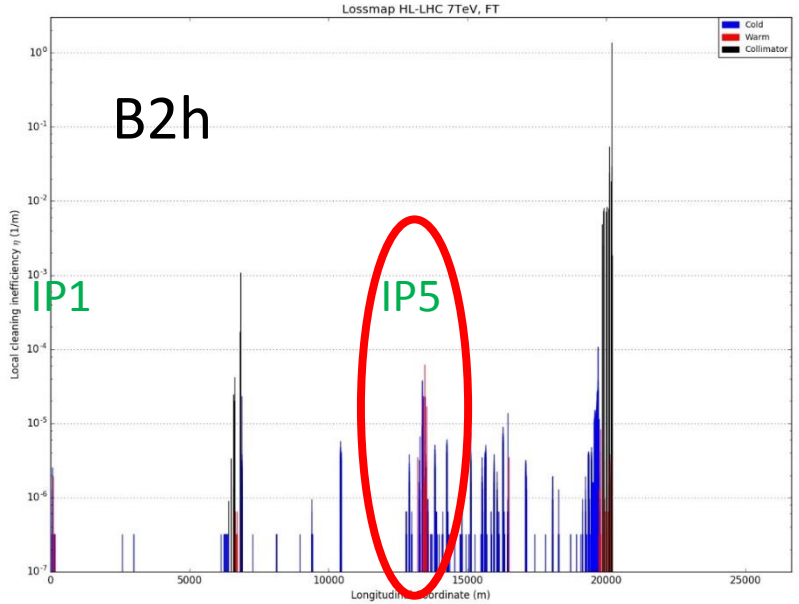
Collimator	Setting collision
TCP IR7	5.7
TCSG IR7	7.7
TCLA IR7	999.0 (10)
TCP IR3	15.0
TCSG IR3	18.0
TCLA IR3	20.0
TCSG IR6	999.0 (8.5)
TCDQ IR6	999.0 (9.0)
TCT IR1/5	999.0 (10.9)
TCT IR2	999.0 (30.0)
TCT IR8	999.0 (15.0)
TCL 4/5/6	999 (12)/ 999 (12)/999 (12)

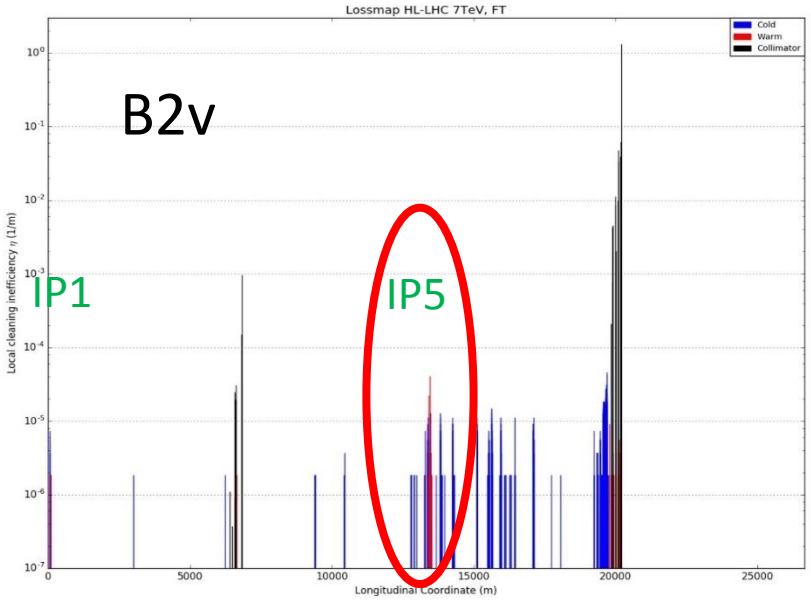
Loss Maps

- B1: losses mainly in IR1 IT;
- B2: losses mainly in IR5 IT;

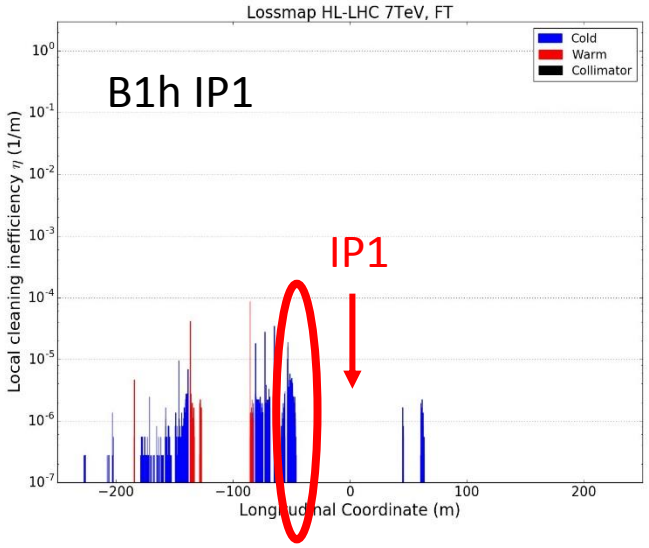


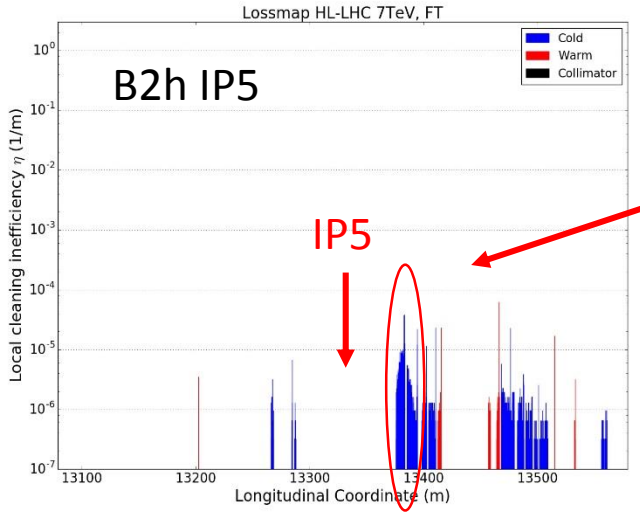




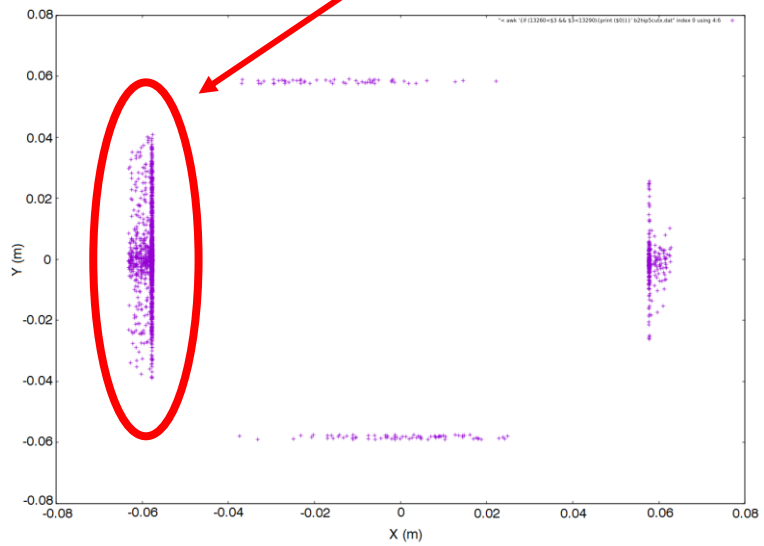


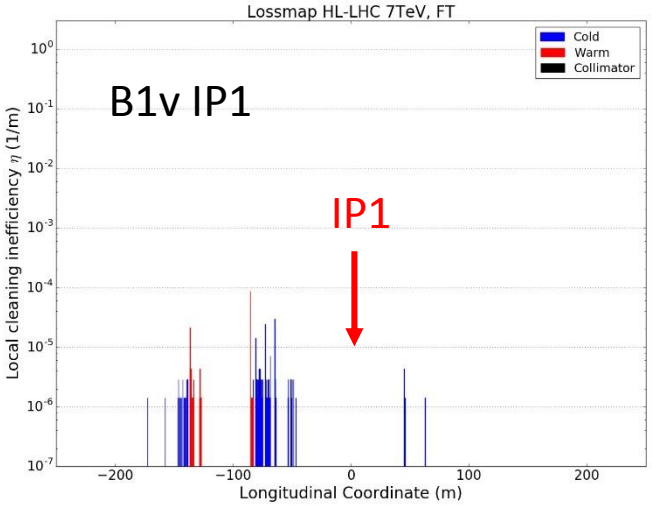
Loss Maps - **Detailed look at IR1 and IR5**

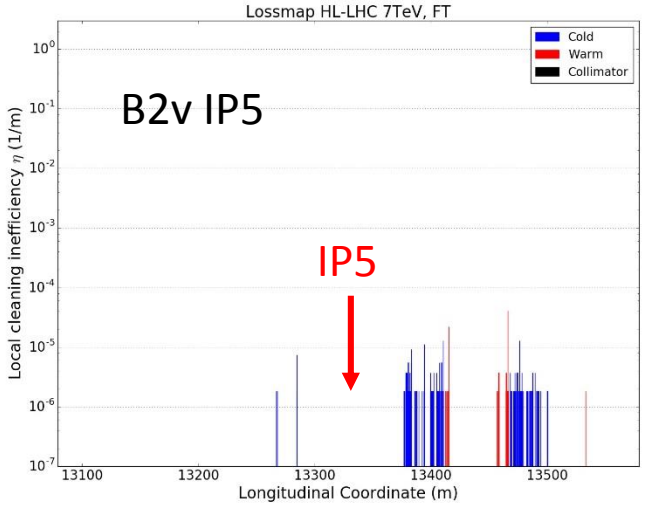




Input for FLUKA simulations

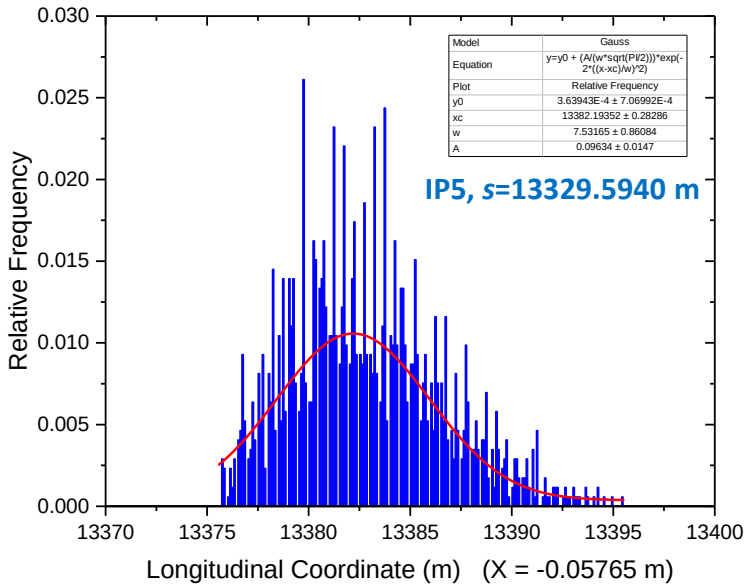


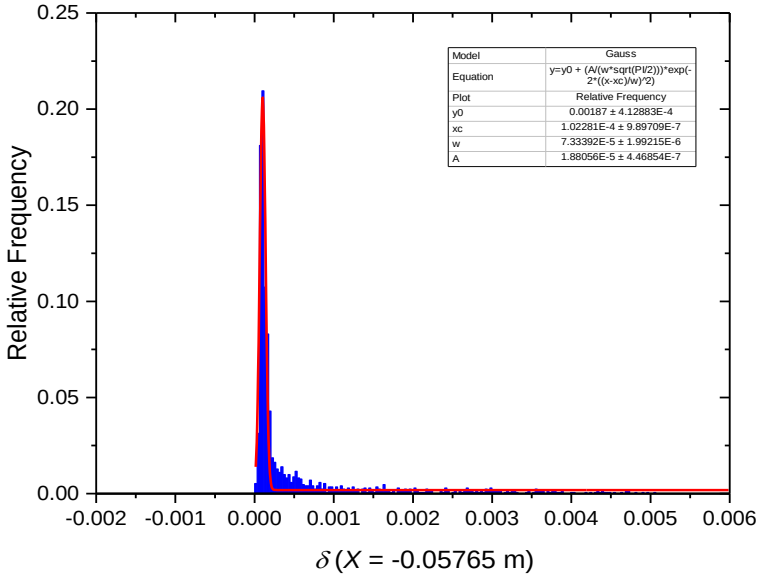




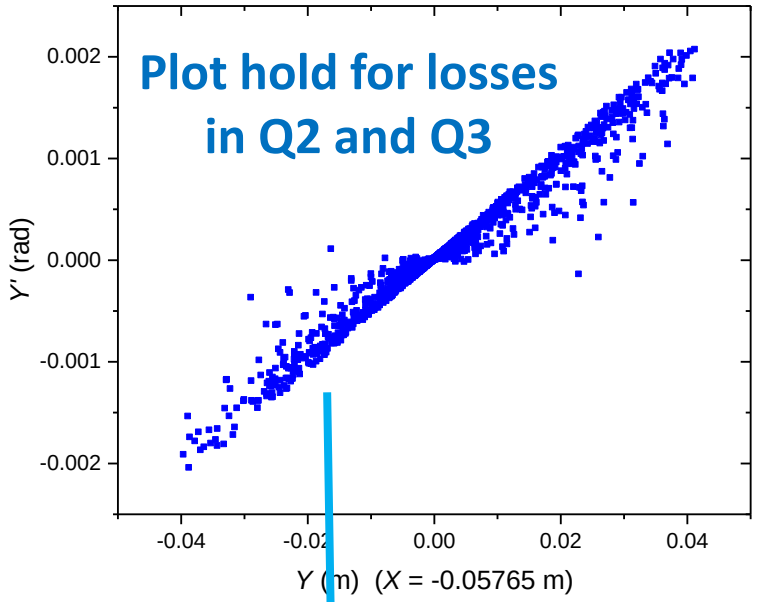
- Losses in the IT are visible mainly for cleaning on the horizontal plane (B1h/B2h);
- When visible, losses in IT are mostly on the H plane;
- Spikes are due to changes in BS dimensions (mainly at BPMs);

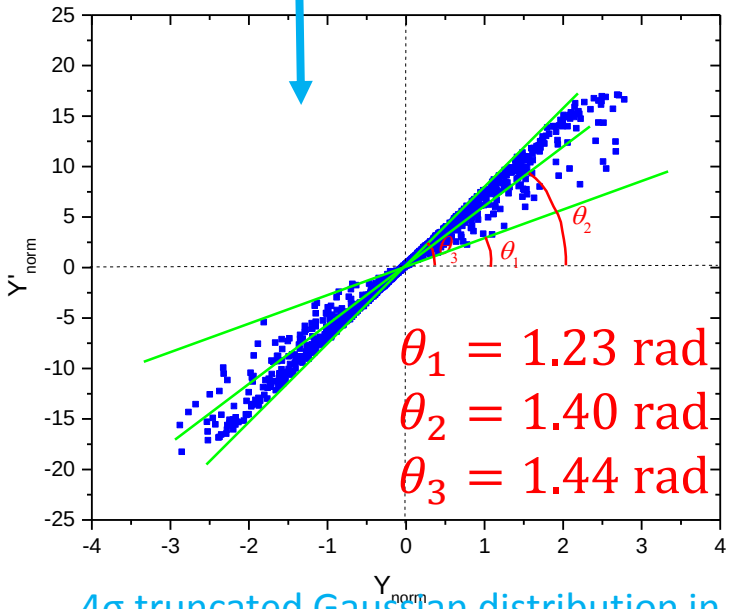
B2h IP5 Right-B4 in B1 reference



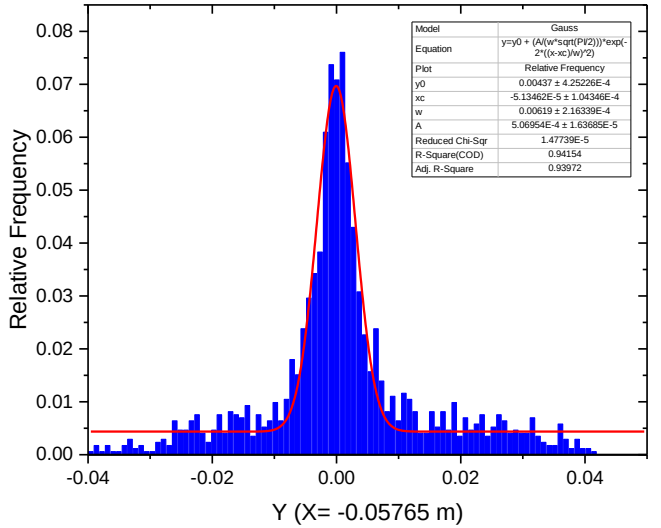


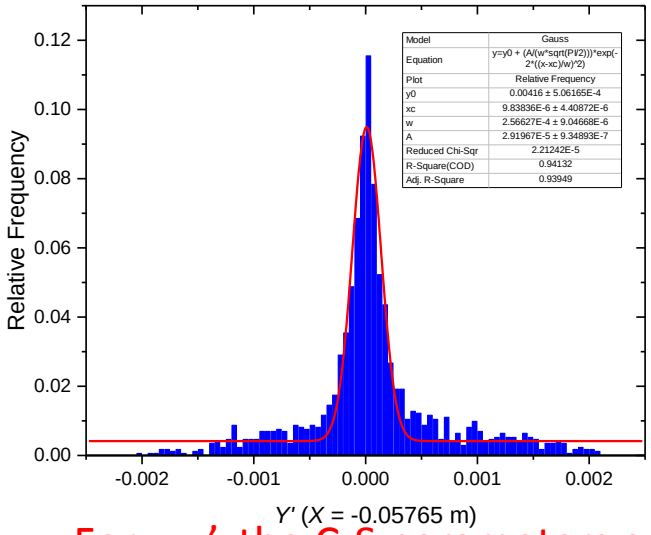
Can be considered as Monochromatic protons





4σ truncated Gaussian distribution in normalized phase space





For y-y', the C-S parameters are

$\alpha_y = -3.21$

$\beta_y = 79.05\ \mathrm{m}$

$\gamma_y = 0.143\ \mathrm{m}^{-1}$

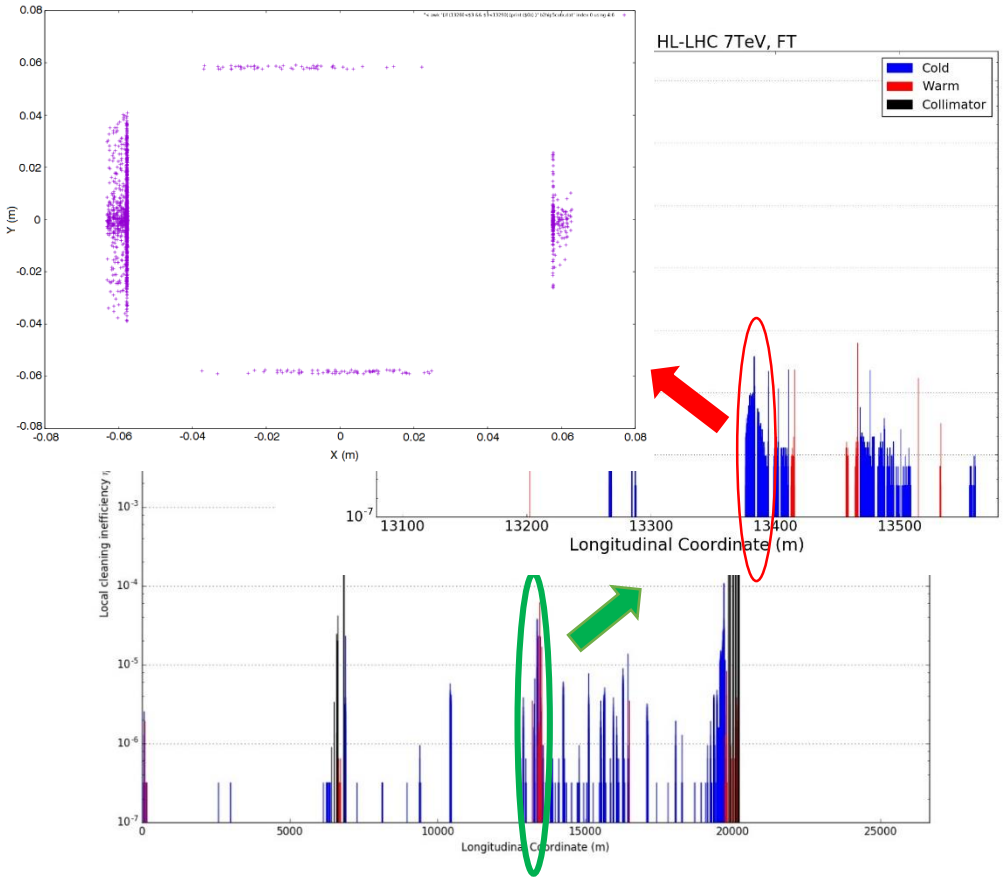
$\varepsilon_{\mathrm{rms}} = 2.34 \times 10^{-7}\ \mathrm{m}$

$\varepsilon_{\mathrm{n}} = 1.75 \times 10^{3}\ \mu\mathrm{m}$

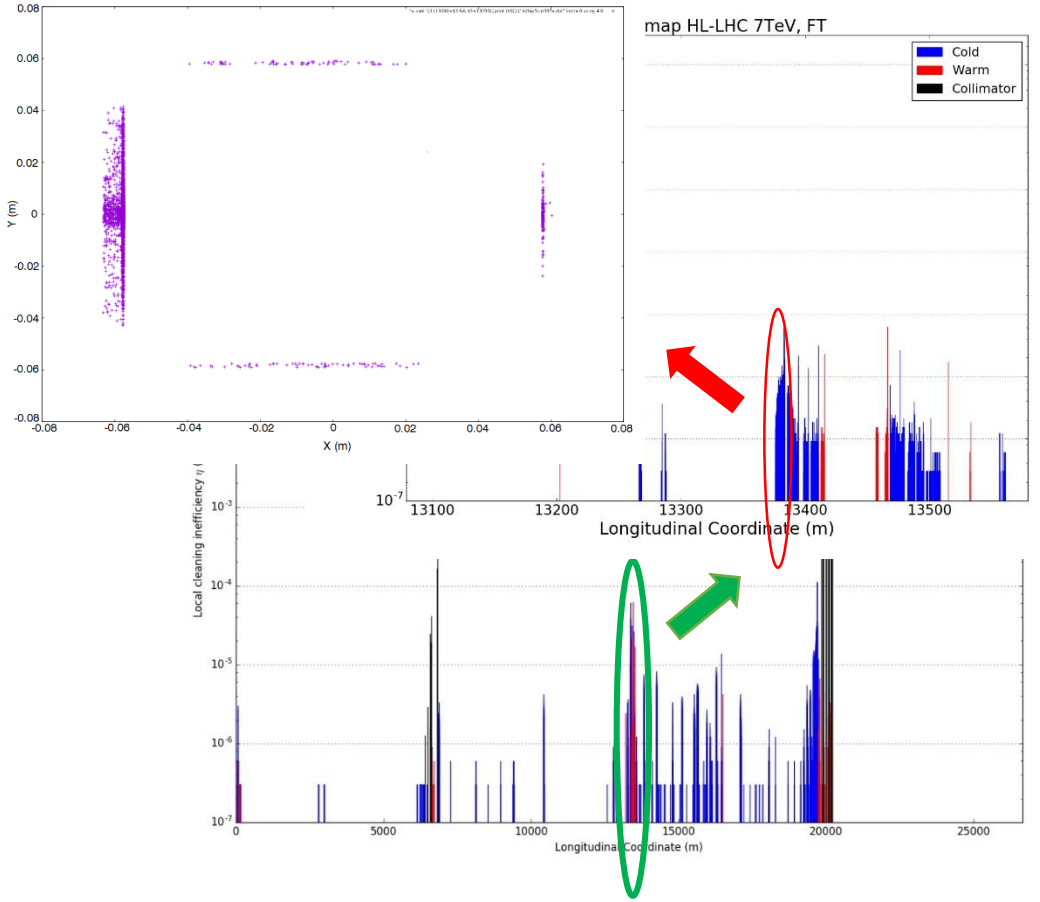
Beam losses comparison with different crossing angle

B2h

295 µrad



395 µrad



Crossing angle (µrad)	Beam losses at Q2 and Q3	Beam losses at X<-0.05 m
295	2112	1723
395	2971	2693
Comparison	40.7%	56.3%

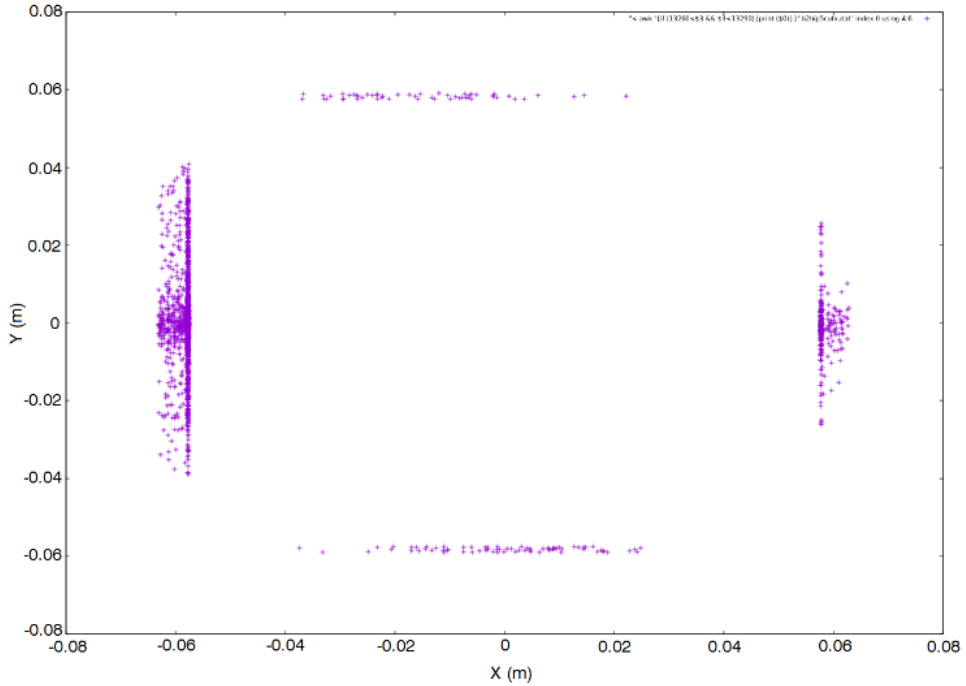
Conclusions

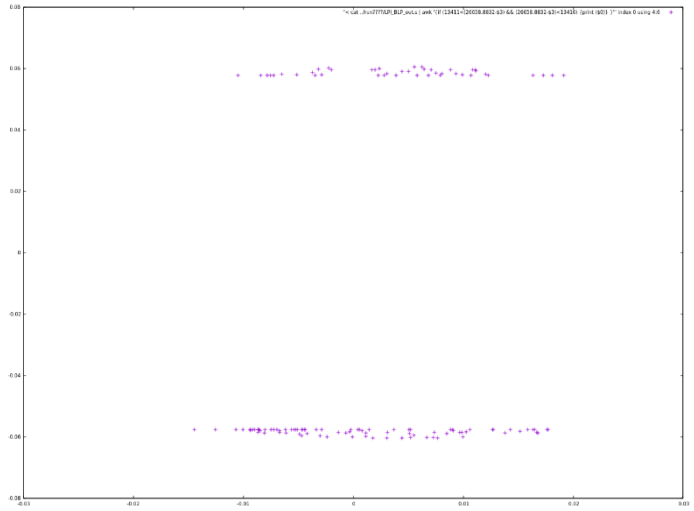
- We are progressing with simulations for cryoBLMs for HL-LHC:
  - Considered loss scenario: missing protection of the IT by TCT collimators;
  - Scanned losses on the four beam/plane combinations, and found the most loaded one being B2H (IR5 IT);
- Loss distribution at the IR5 IT has been characterized:
  - Fits / analytical expressions have been found and passed onto the FLUKA team for the endep studies;
- Outlook:
  - Scan possible crossing schemes in IR1/5 (e.g. plane of crossing and sign of angle), to see if there is a specific configuration further decreasing the normalized aperture of the IT;
  - Check levels with regular cleaning?

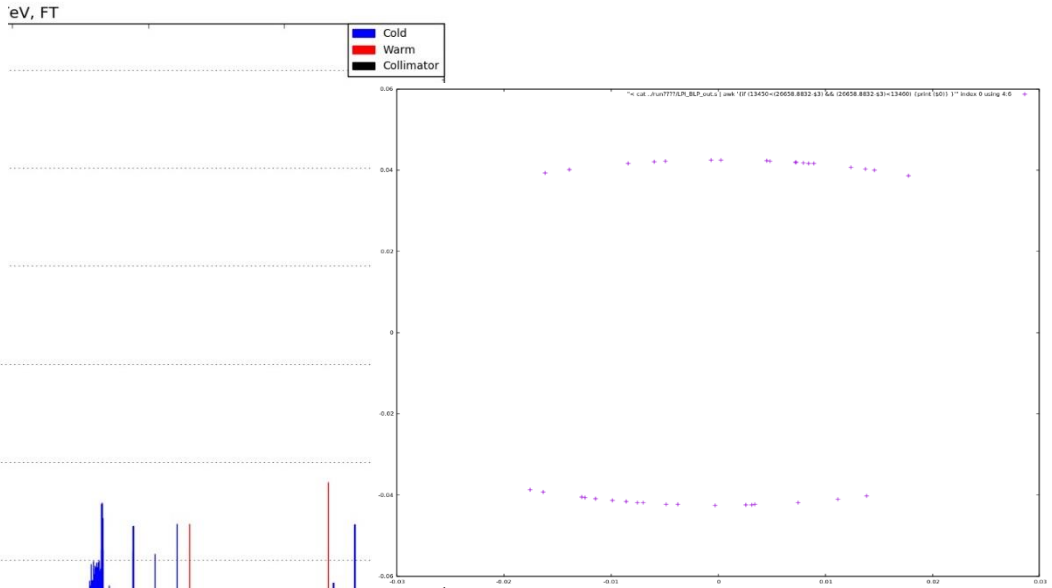
Thanks

Back-up

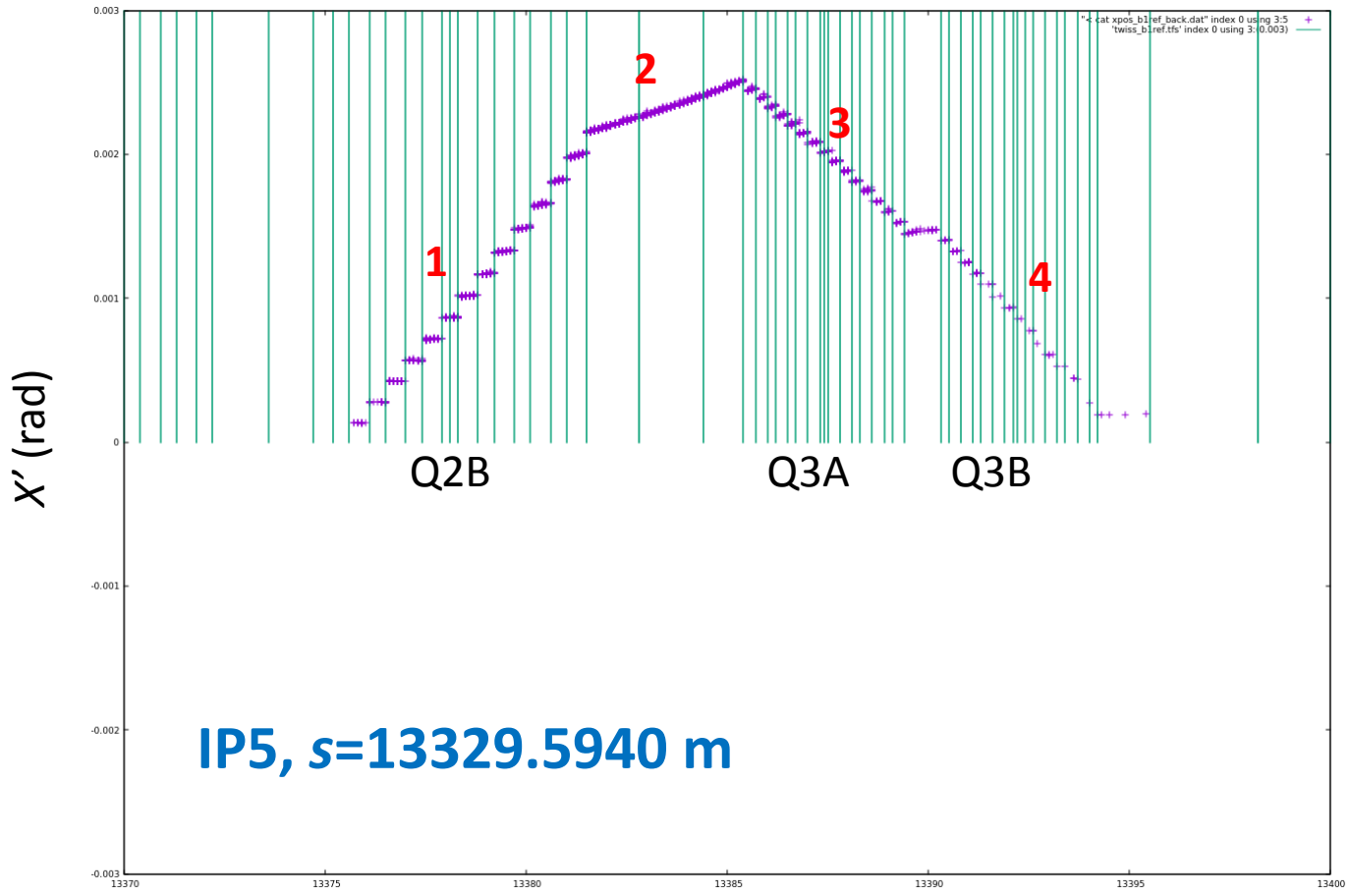
B2h IP5


0.08
0.06
0.04
0.02
0
-0.02
-0.04
-0.06
-0.08
Y (m)
-0.08
-0.06
-0.04
-0.02
0
0.02
0.04
0.06
0.08
X (m)




eV, FT
Cold
Warm
Collimator
Local cleaning inefficie
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
IP5
13150
13200
13250
13300
13350
13400
13450
13500
Longitudinal Coordinate (m)

Correlation of X' with *s*



Beam losses in *X'* have correlation with *s*, *according to the equation:*

$$X'[\mathrm{rad}] = m_i s[\mathrm{m}] + q_i$$

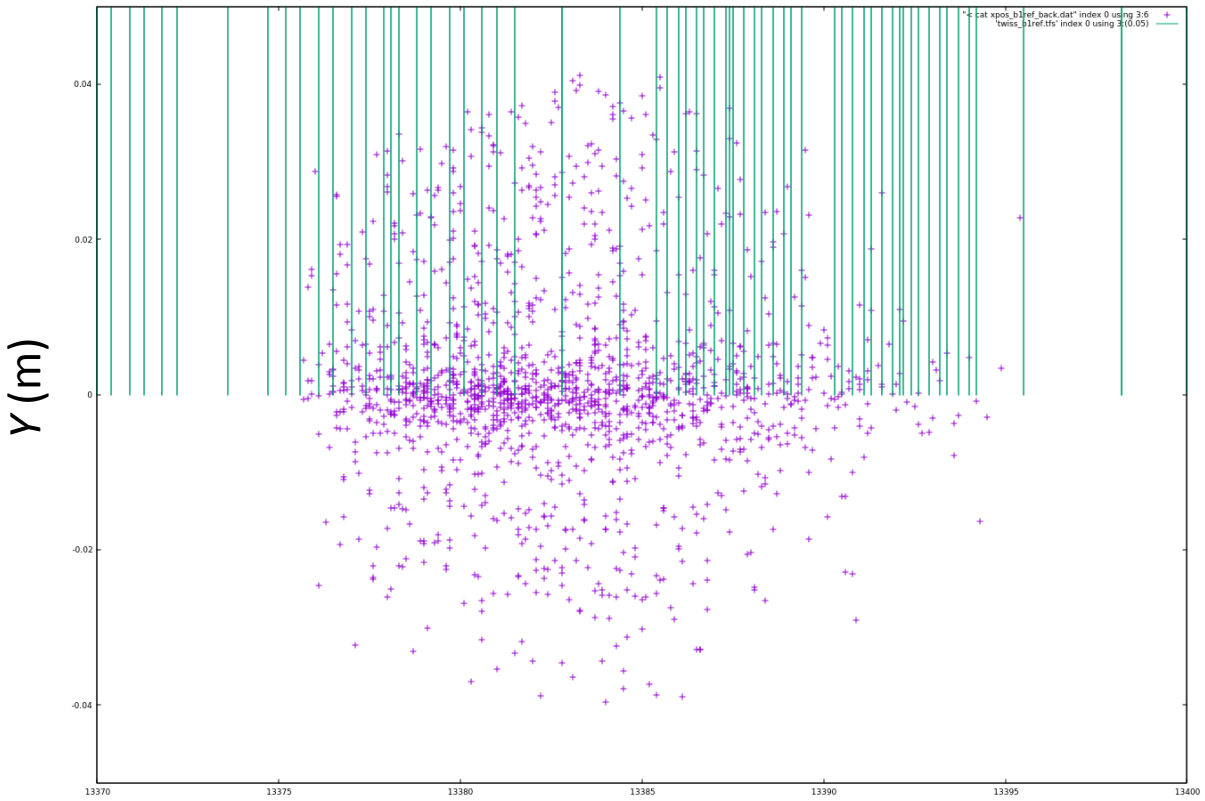
$$i = 1 \sim 4$$

s from 13375.7 m to 13381.5 m, $i = 1$,
s from 13381.5 m to 13385.4 m, $i = 2$,
s from 13385.4 m to 13389.4 m, $i = 3$,
s from 13390.3 m to 13394.3 m, $i = 4$,

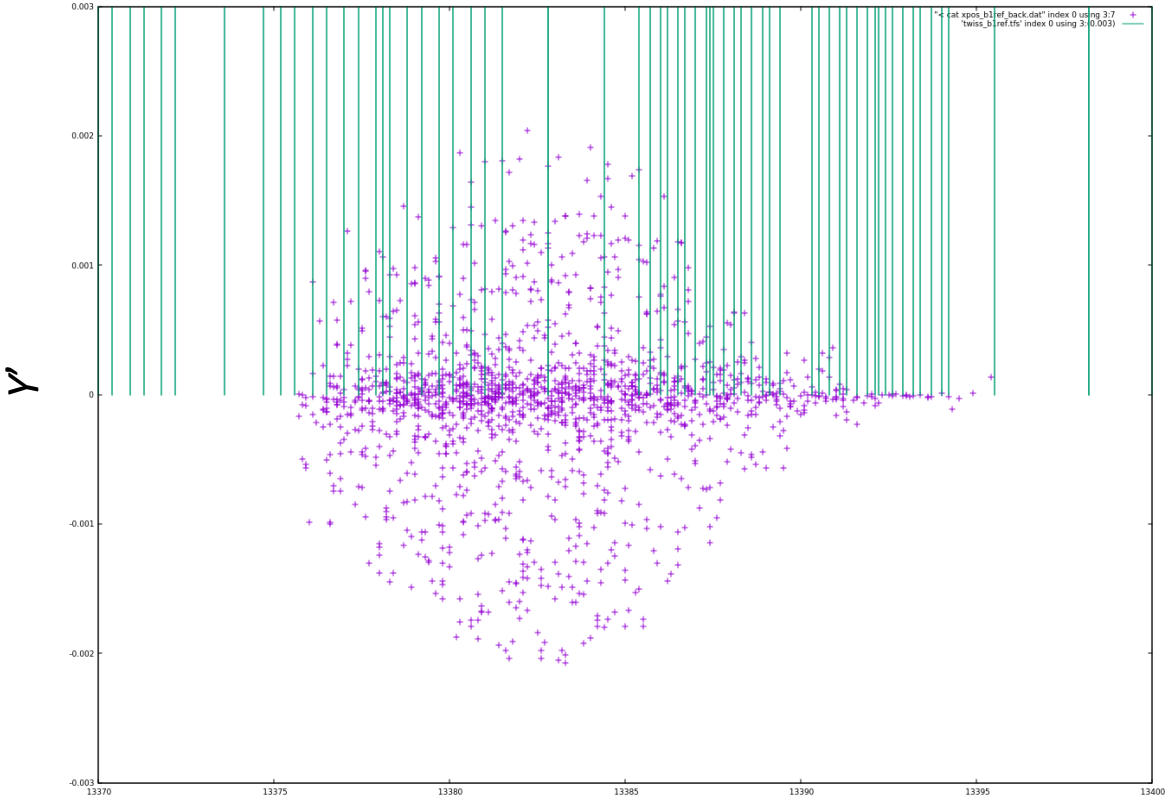
The coefficients are fit as,

$m_1 = 3.4176\mathrm{E}-4, q_1 = -4.5712$
$m_2 = 9.1779\mathrm{E}-5, q_2 = -1.2260$
$m_3 = -2.4771\mathrm{E}-4, q_3 = 3.3182$
$m_4 = -2.9733\mathrm{E}-4, q_4 = 3.9827$

Correlation of y-y’ with *s*



Longitudinal Coordinate (m)



Longitudinal Coordinate (m)

Beam losses in *Y*, *Y’* plane have no correlation with *s*

Energy spread zoom to δ = 0.001