Update on radiation damage calculations for the HL-LHC betatron cleaning insertion

E. Skordis

On behalf of the FLUKA and Collimation teams

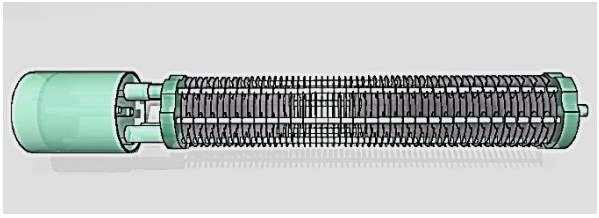
Energy deposition simulation requirements for collimation losses

1. Creating input for further FLUKA simulations

   New method: Sixtrack-FLUKA Coupling provides input (lossmap of proton impacts on collimator surface)

2. FLUKA simulation set up
   - Model complex geometries of all key elements of the LHC
   - Set up the simulation parameters
     - Source routine
     - Magnetic fields routines
     - Physics settings
     - Scoring
     - Etc…

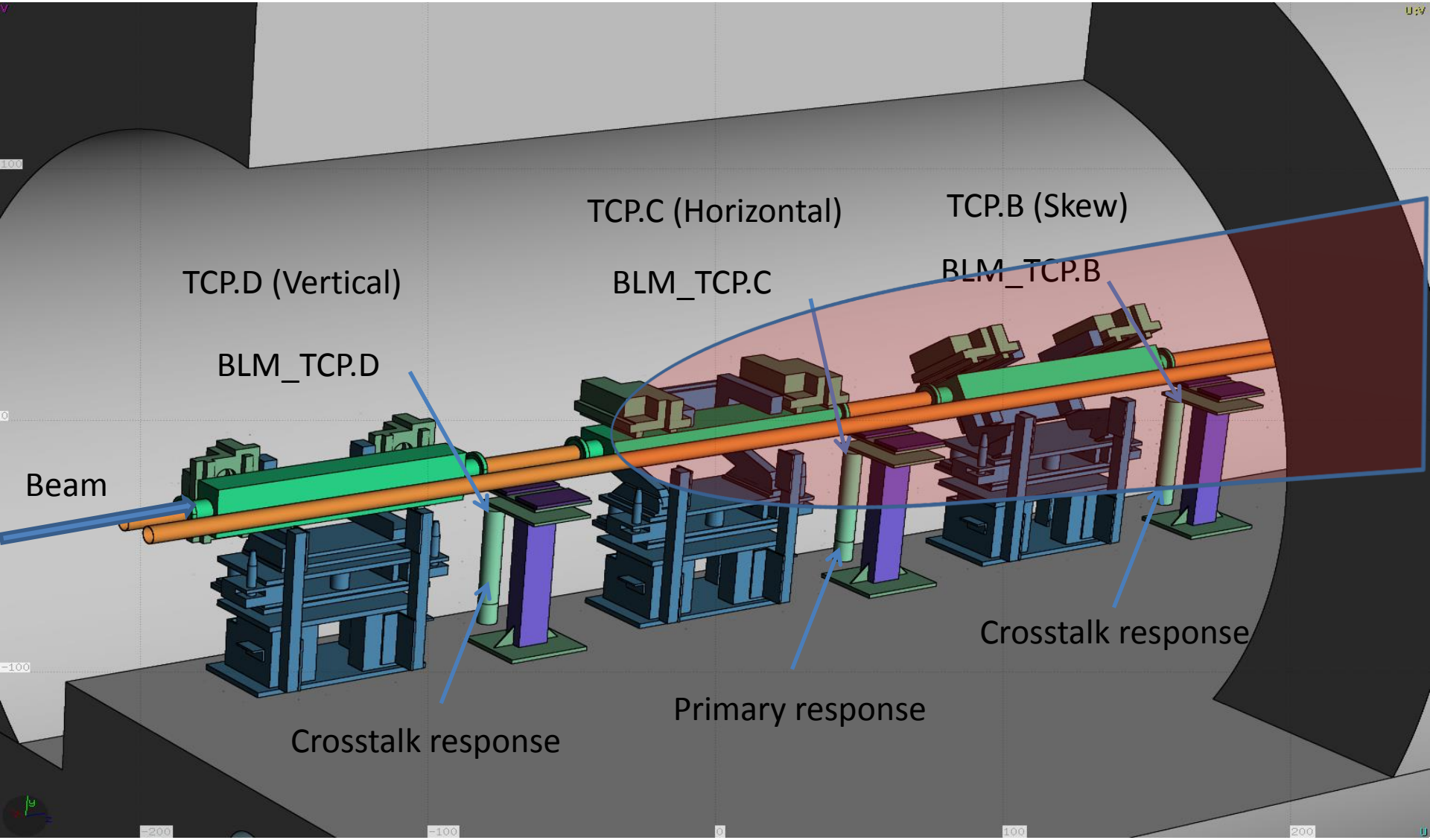
LHC BLM



FLUKA MODEL

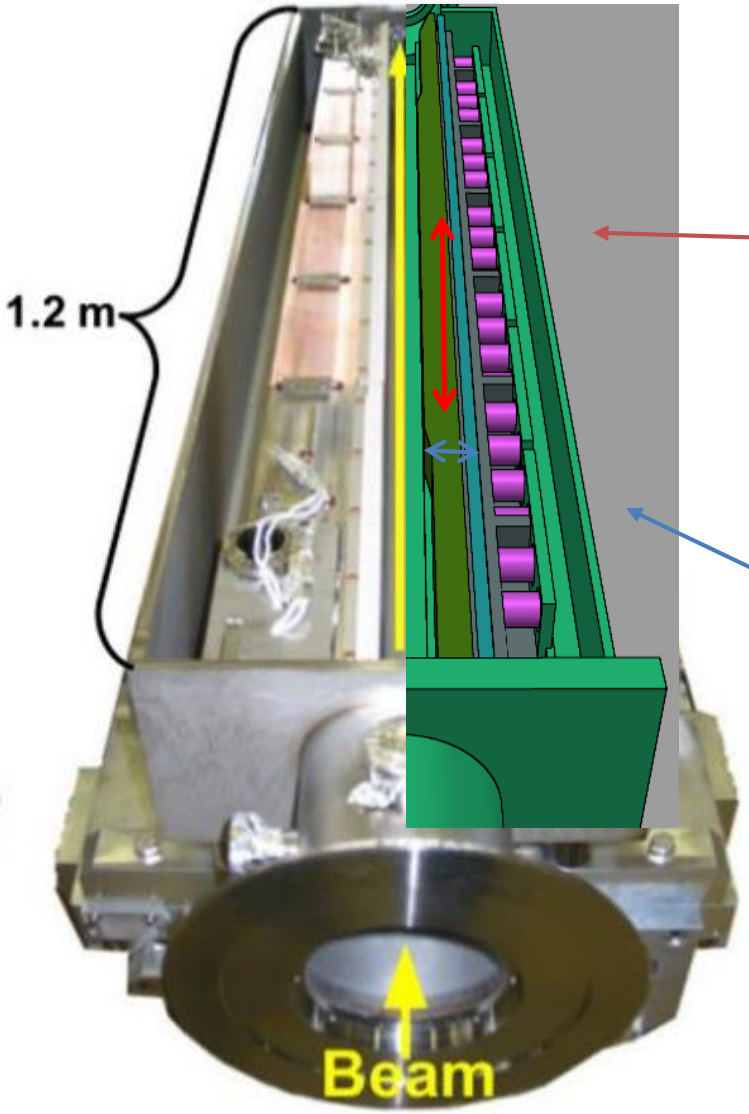
Picture

TCP simulated Geometry

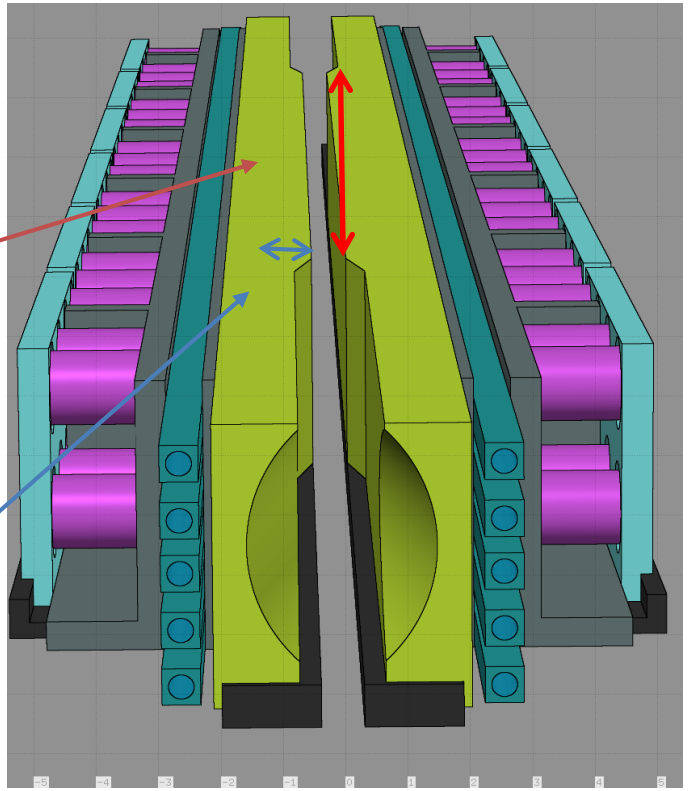


Useful dimensions and coordinate system

TCP.C6L7



Longitudinal distance from collimator center (z)
-30<z<30 (cm)

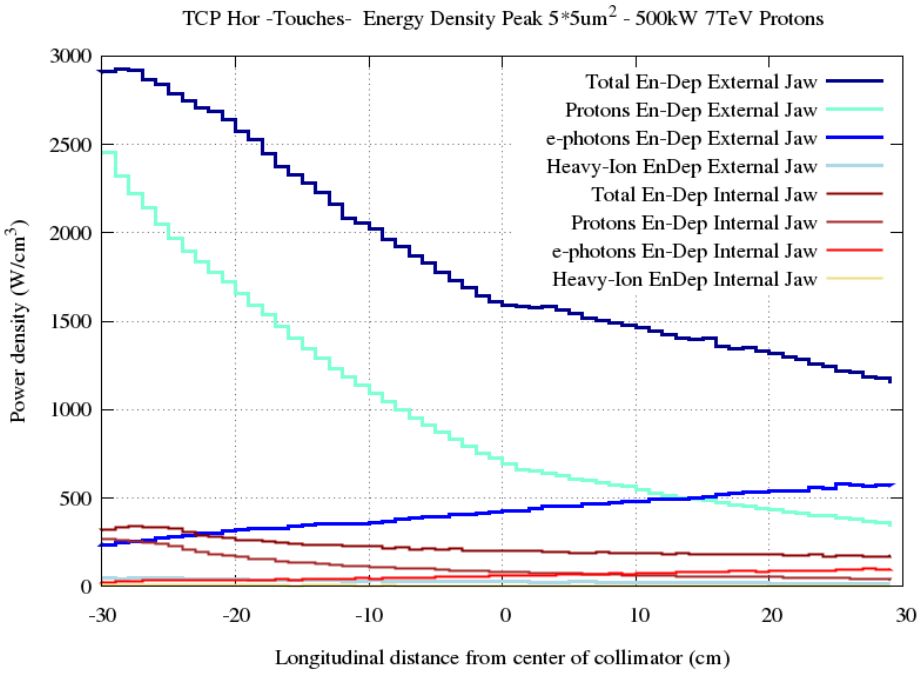


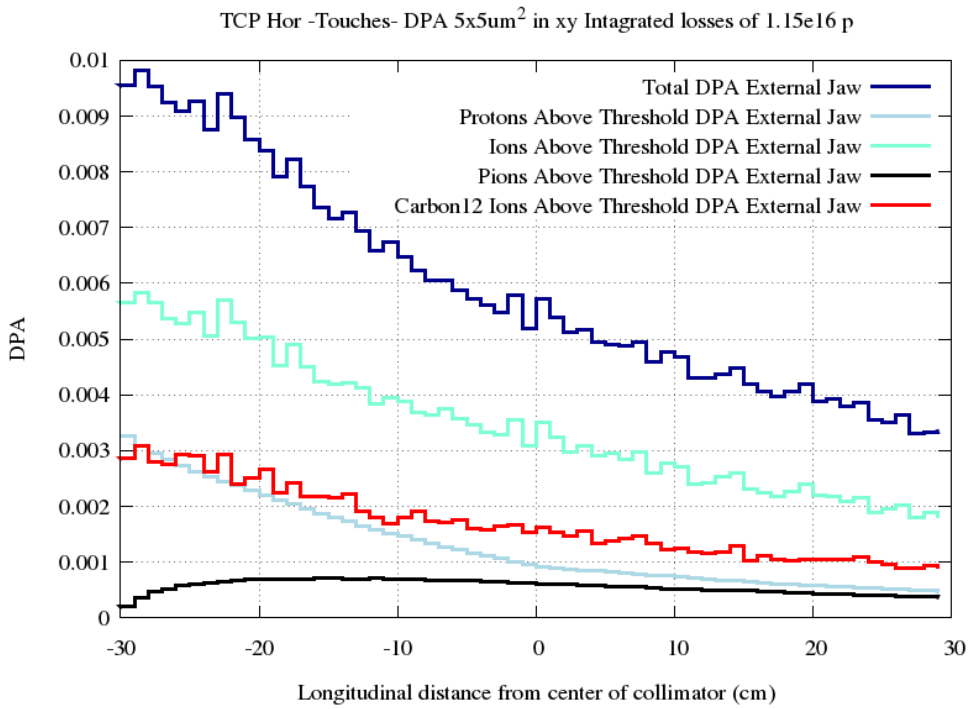
Transverse distance from collimator surface (x)
0<x<0.04 (cm)

External = Positive Jaw
Internal = Negative Jaw

EuCARD² – Malta Results overview Primary Horizontal

500kW of 7 TeV/p = 4.5e11p/s





- The remaining energy deposition is attributed to other charged particles (i.e. Pions)

Total Power <u>deposited</u> in both Jaws: 3kW

- Carbon 12 contribution included in the Ions!

1.15e16p ≈ 30-40 fb^{-1}

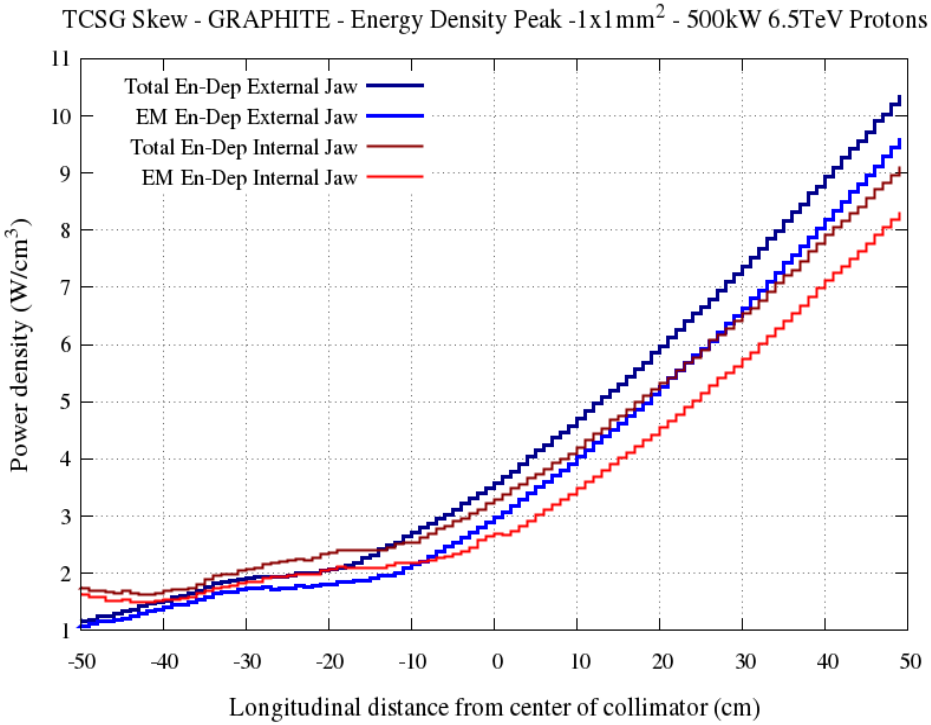
Area of impact 0.005*0.1=5e-4cm^2

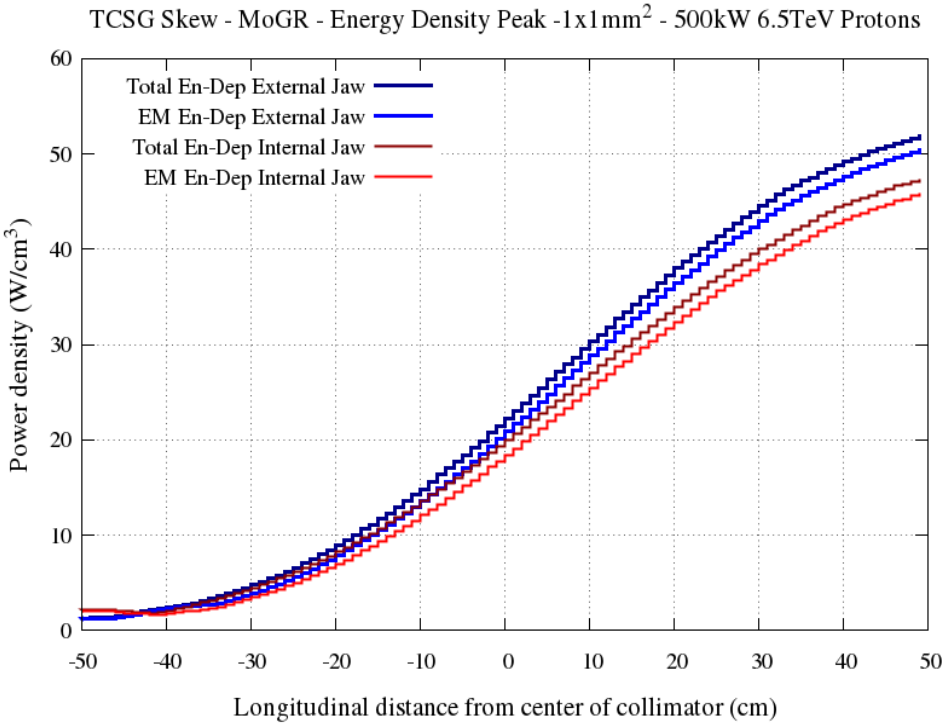
Multipass factor = 1.5 - Fluence = 3.45e19p/cm^2

<u>a factor of ~100 more for HL-LHC</u>

EuCARD² – Malta Results overview Skew TCSG

500kW of 6.5 TeV/p = 4.85e11p/s



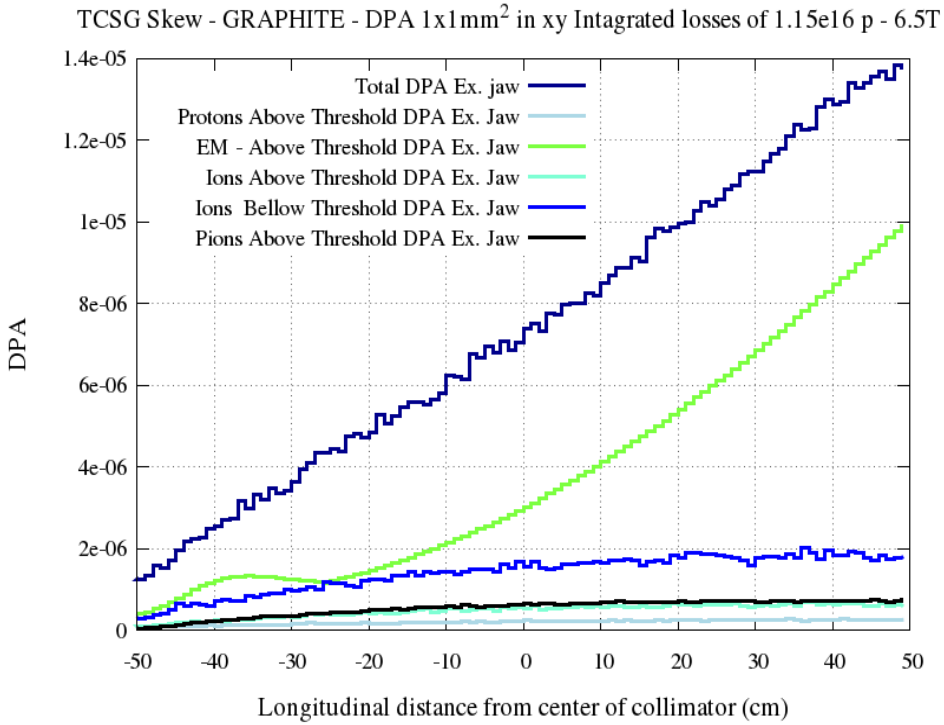


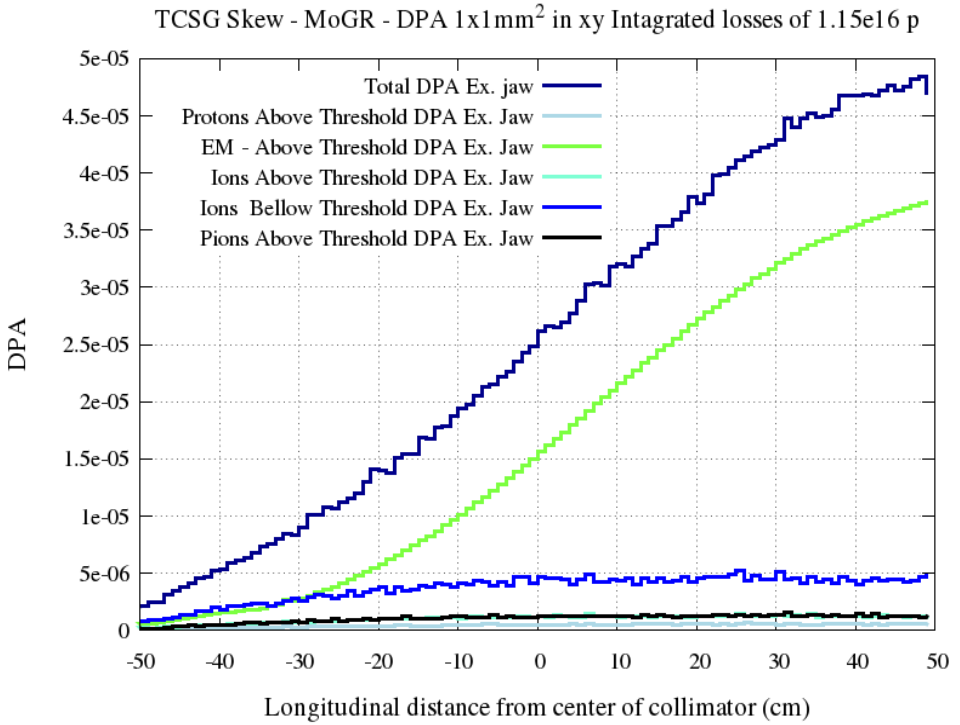
Total Power deposited in both Jaws for GRAPHITE: 15kW

Total Power deposited in both Jaws for MoGR: 37.5kW

- The remaining energy deposition is attributed to other charged particles (i.e. Pions,Kaons)

EuCARD² – Malta Results overview
Skew TCSG





1.15e16p ≈ 30-40 fb^{-1}

a factor of ~100 more for HL-LHC

IP7 losses scaling and impact on forecast for HL-LHC era

Year	Integrated Luminosity (fb^{-1})	Integrated Intensity* (ps)	Lost Protons (FLUKA + BLM)	Lost Protons (2015 scaled)	Lost Protons (Old scaling)
				Intensity	Luminosity
2015	4.2	7.6×10^{20}	6.2×10^{14}		1.2×10^{15} (2)
2016	40	2.6×10^{21}	1.5×10^{15}	2.1×10^{15} (1.4)	**1.15×10^{16}** (7.7)
2017**	44	2.1×10^{21}	1.6×10^{15}	1.7×10^{15} (1.1)	1.2×10^{16} (7.5)
HL-LHC***	3000	~10^{23}	-	**8.4×10^{16}**	~8.6×10^{17} (~10)

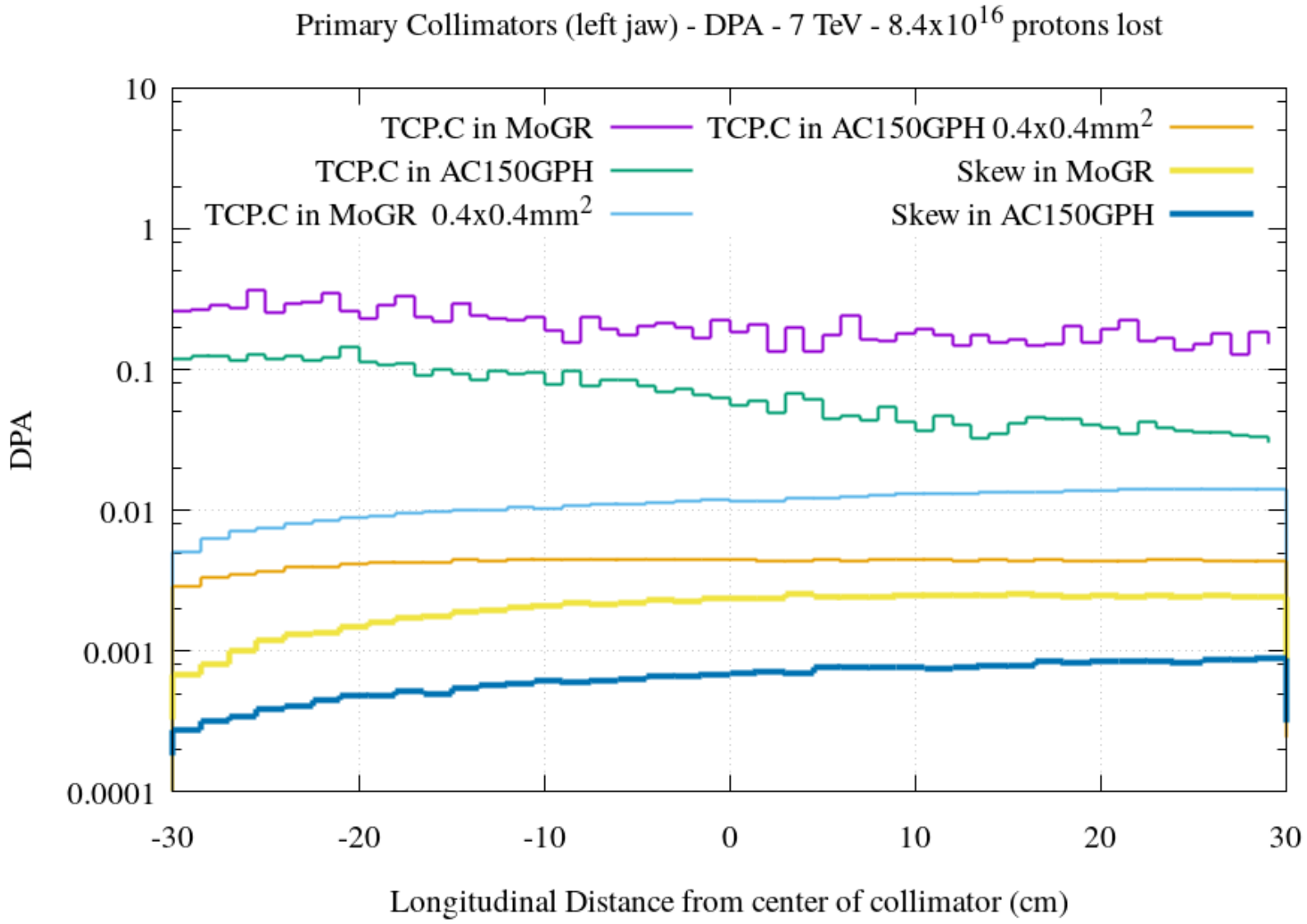
In brackets, ratio between scaled and measured protons lost

** Integrated pp intensity considering both beams*
***Analysis up to 25-10-2017*
****Estimated annual intensity calculation (Andrea Apollonio)*

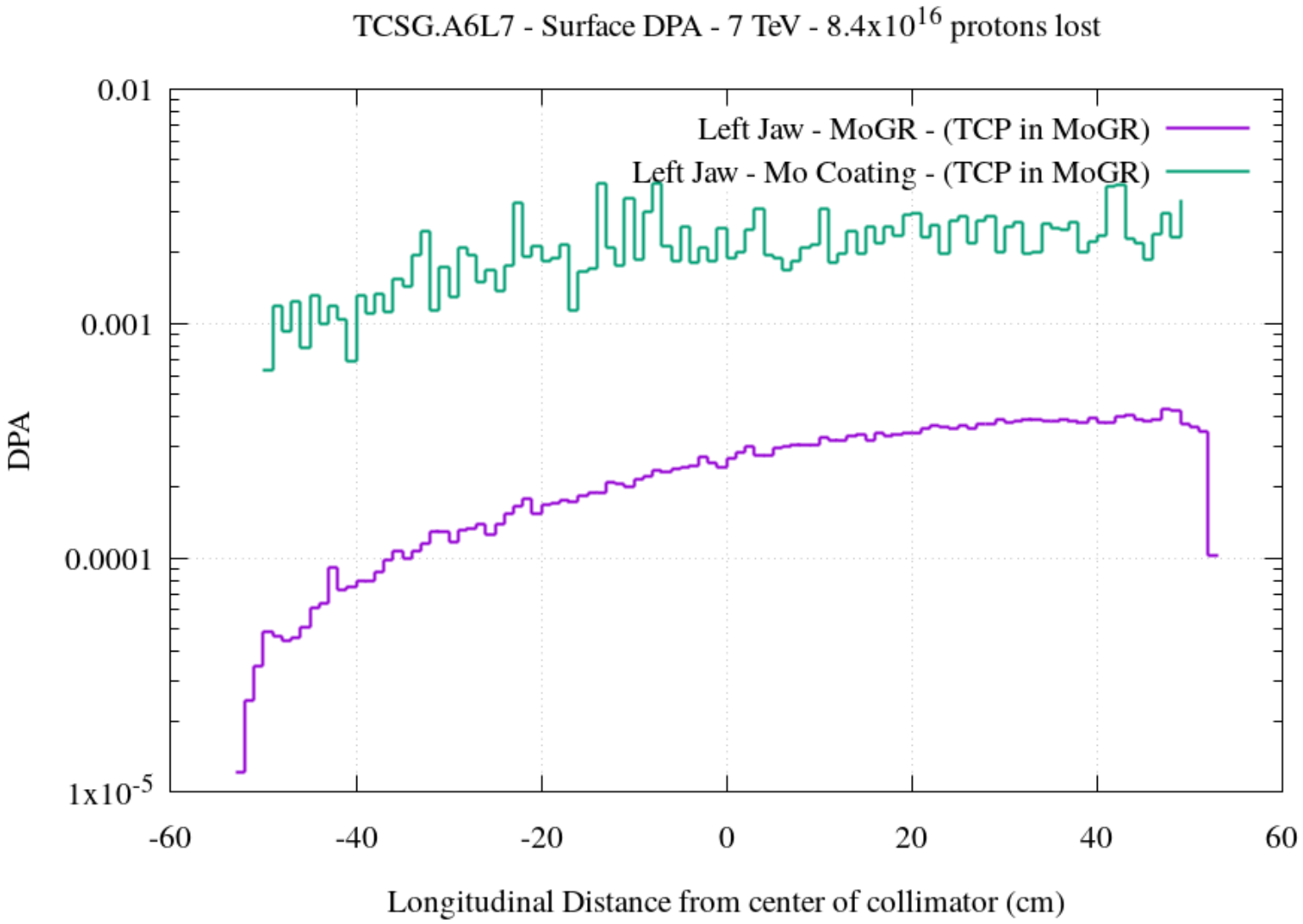
- Confirmation that despite the different operational scenario, integrated **intensity** scaled losses from 2015 are in **good agreement** (within **factor 1.5**) with 2016 and 2017 measurements
- When scaled with integrated **luminosity given the old normalisation** results are **highly overestimated**

Rubén García Alía, November 15th, 2017
HL-LHC annual meeting

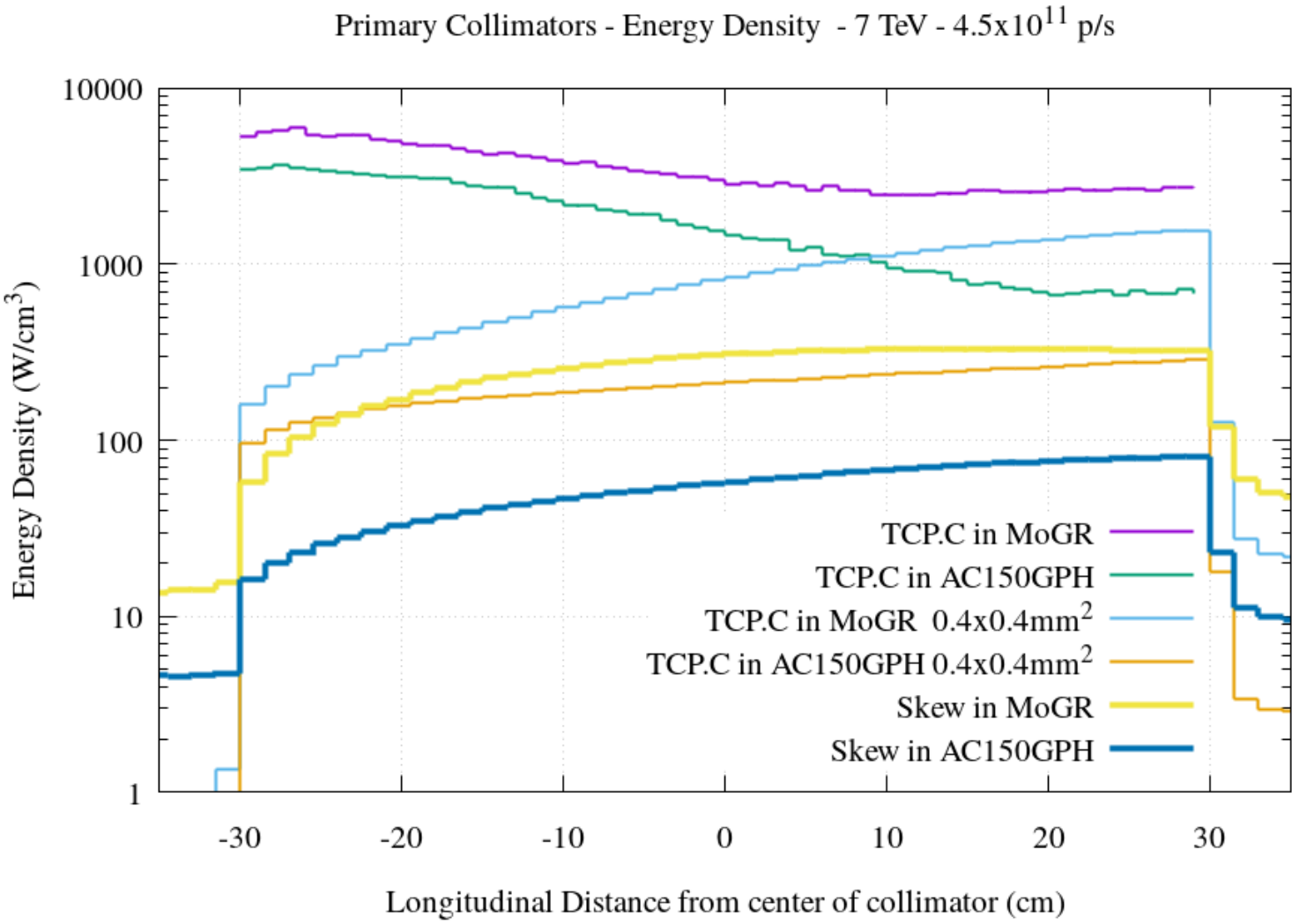
7 TeV HL-LHC settings / 2 sigma retraction



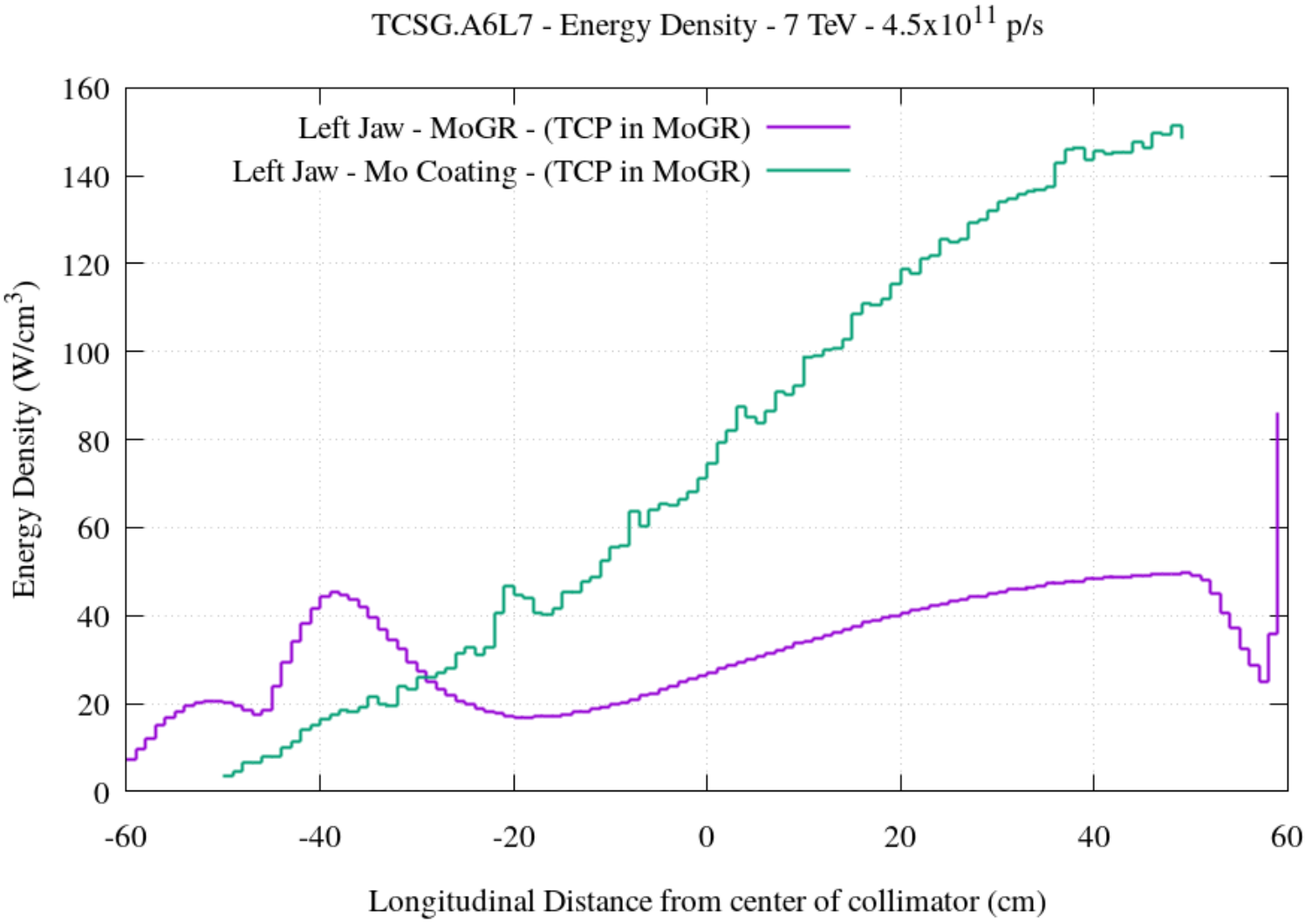
7 TeV HL-LHC settings / 2 sigma retraction



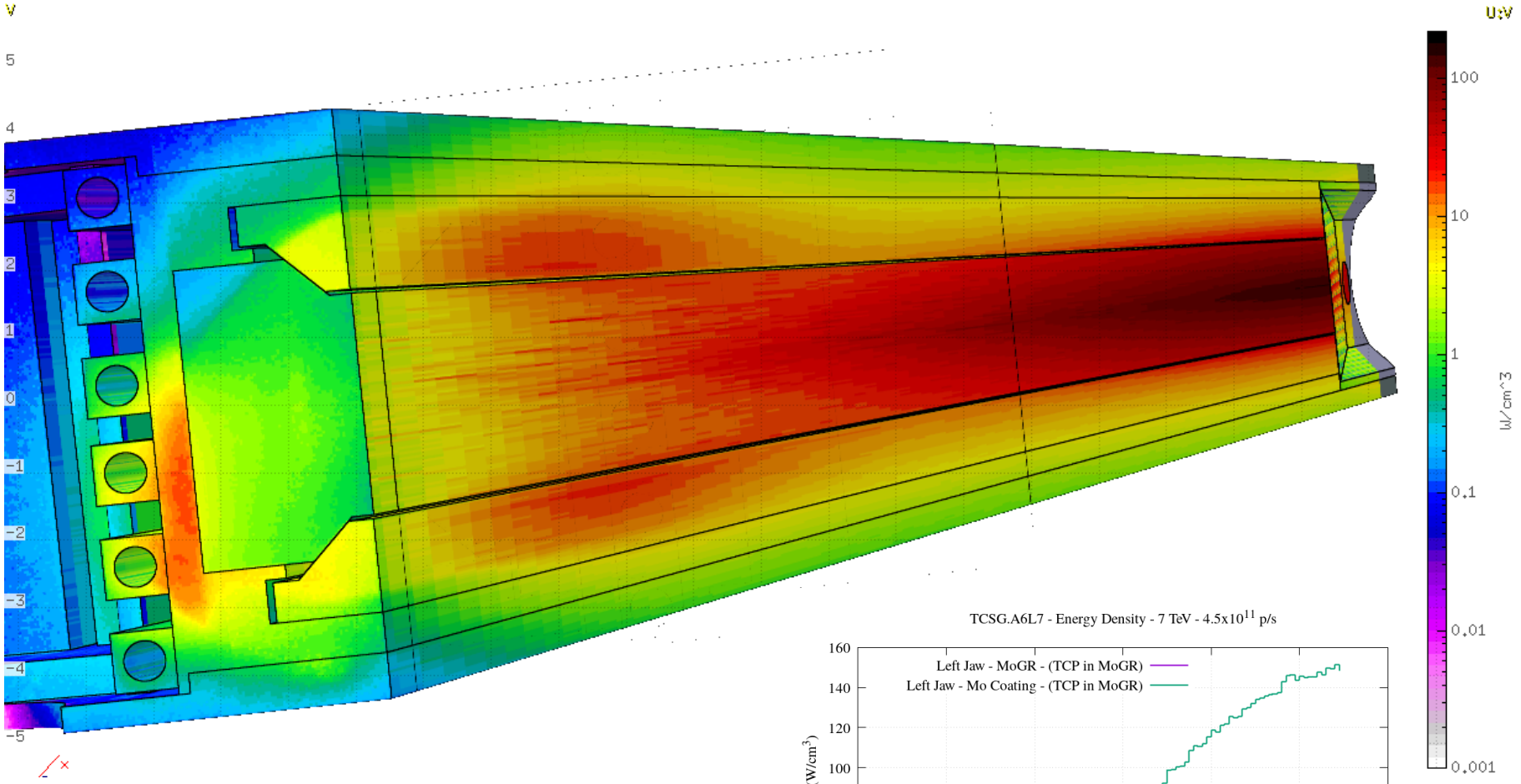
7 TeV HL-LHC settings / 2 sigma retraction

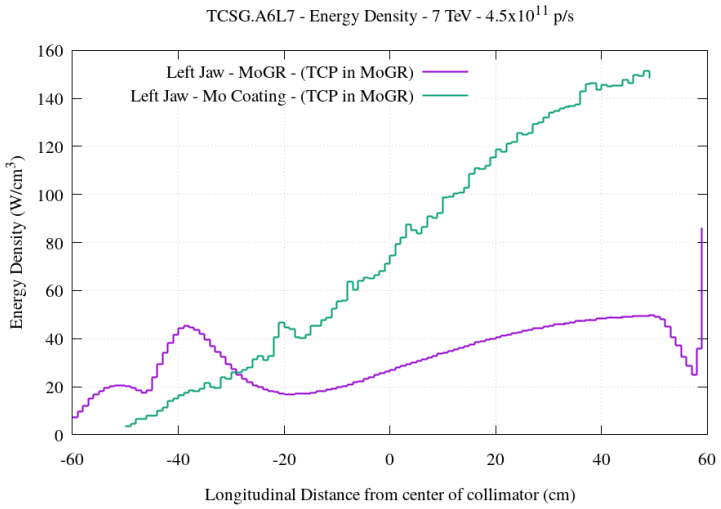


7 TeV HL-LHC settings / 2 sigma retraction



7 TeV HL-LHC settings / 2 sigma retraction





Conclusions

A. New scaling method based on proton circulation time (ps) much better predictability based on 2015-2017 data

- A factor of ~10 less total proton lost in the collimation system compared to the old scaling with luminosity
- Revaluation for predicted DPA values for the HL-LHC lifetime (8.4×10^{16} protons lost)

Collmator -> Material ⬇	Primary Horizontal	Primary Skew	Secondary in MoGR (with Mo coating)
MoGR	0.3	2.5×10^{-3}	4×10^{-4}
AC150 (Mo coating)	0.12	9×10^{-4}	(2×10^{-3})

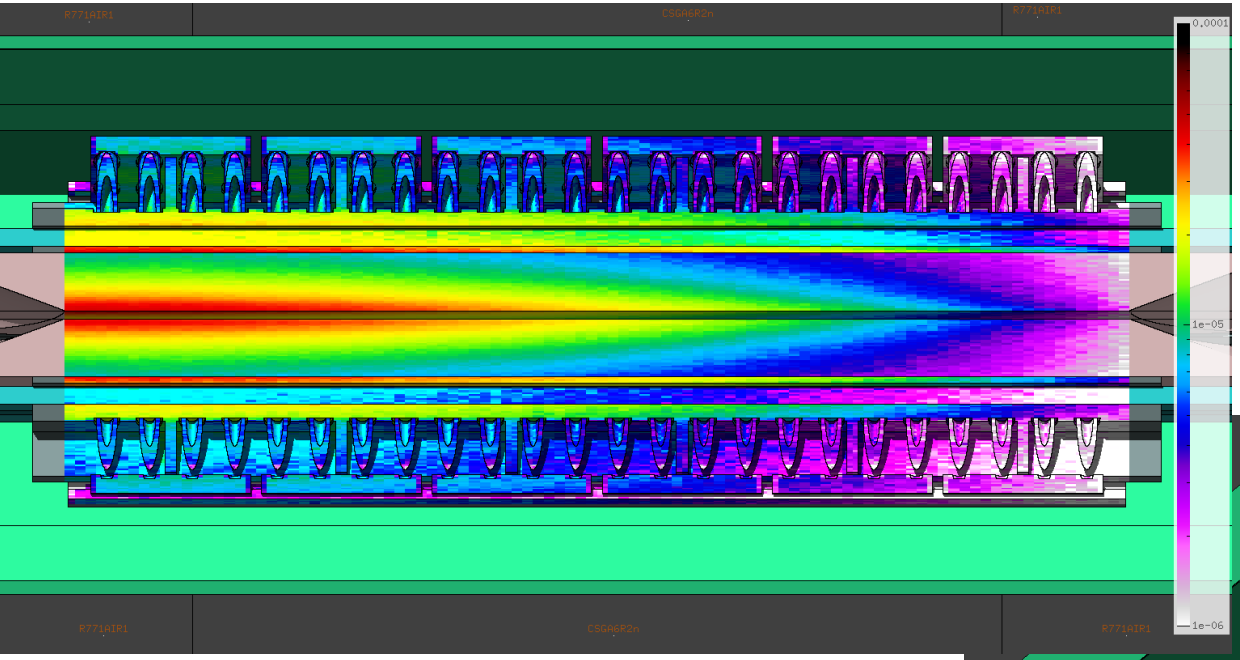
B. New results (both DPA and Energy density) :

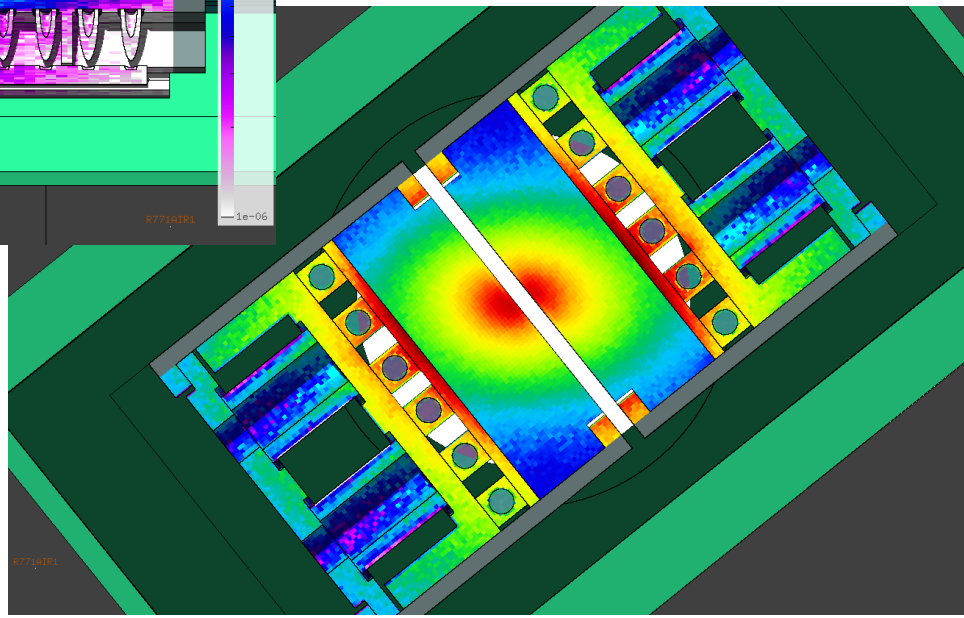
- For Skew collimator in both MoGR and AC150GPH
- For newly considered Mo coating -> Energy density gradient between coating and MoGR could cause stresses?
- For primary horizontal in MoGR -> Energy density values in the order of 5kW peaked and 1.8 averaged on a 0.4*0.4 mm^2

Thank you!

BACK UP SLIDES

DPA x-sec for MoGR for 1x1mm^2 bin size

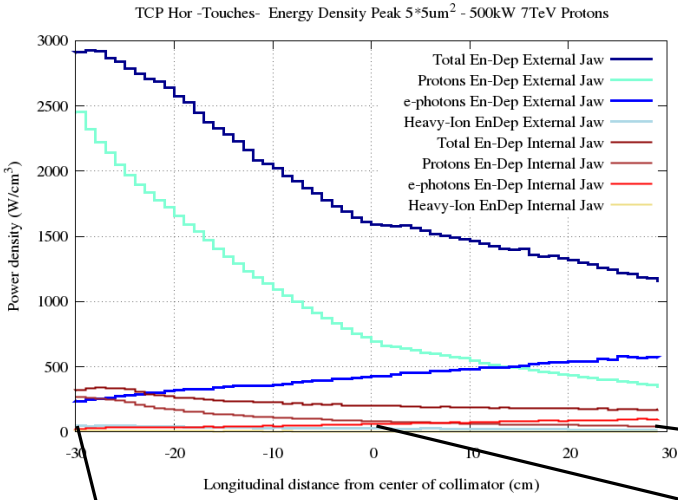


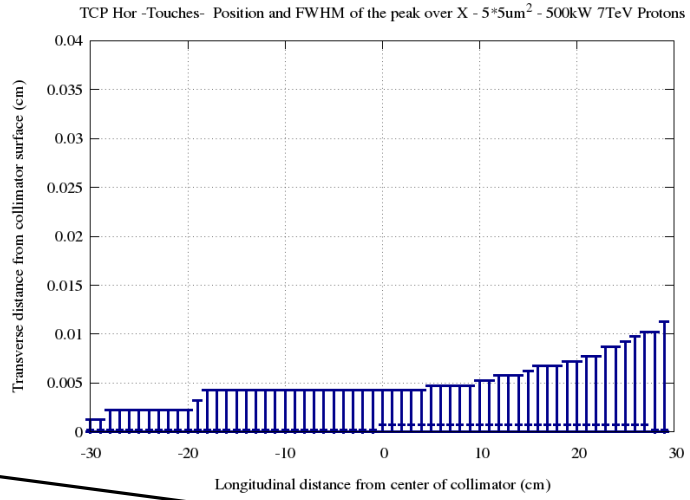


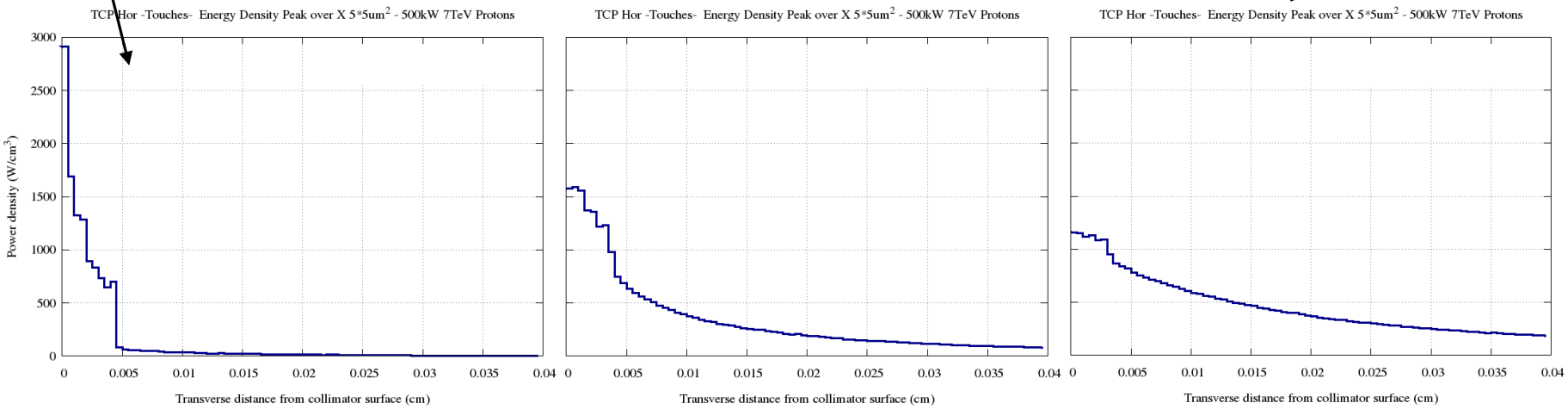
1.15e16p ≈ 30-40 fb^{-1}

a factor of ~100 more for HL-LHC

Peak power density over X for 5x5μm² bin size







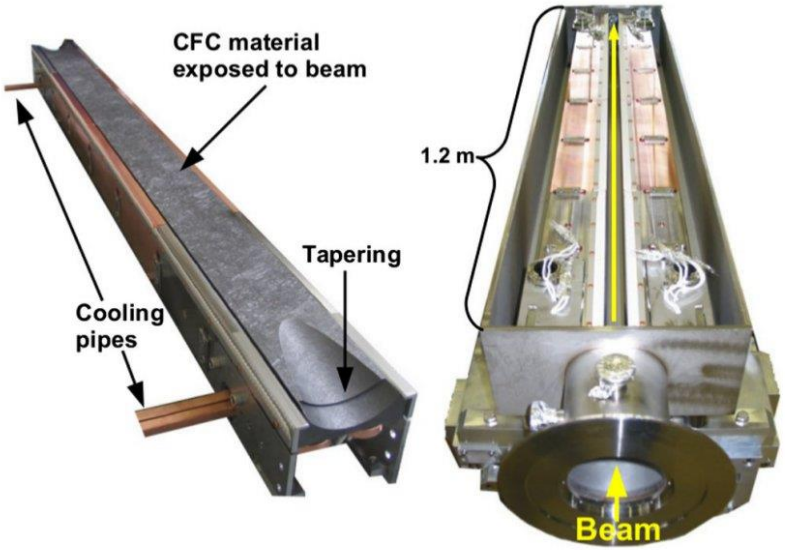
- Strong surface effect especially on the first 5um in X

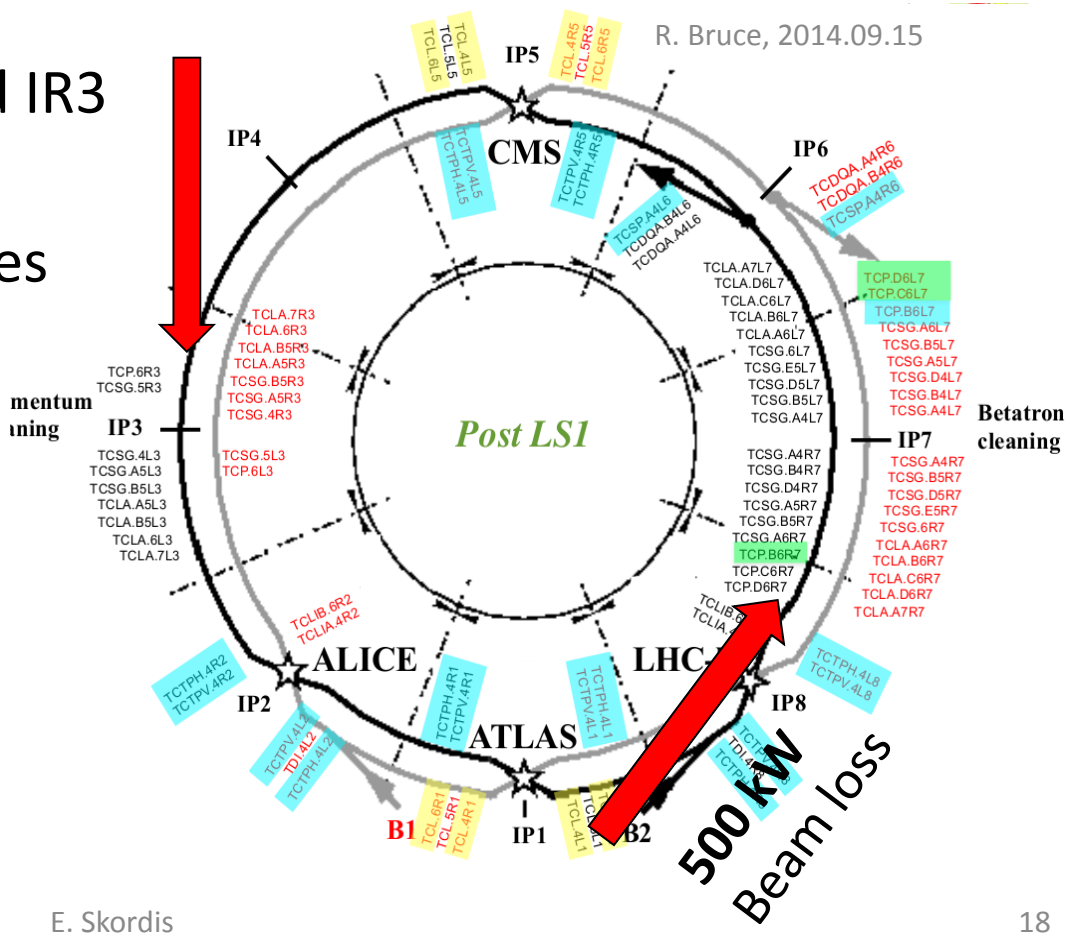
LHC collimation system

- Capable of redirecting up to 500kW of proton loss rate in order to protect the Super Conducting Magnets from quenching (stop being SC due to energy deposition -> increase in temperature)
- 99% of that power is

deposited in the whole IR7 and IR3

- **Not** all power is absorbed by the collimators themselves



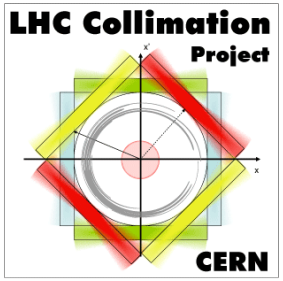


Collimation losses simulation overview

- Simulation tools used:

Sixtrack and FLUKA are simulation tools regularly used at CERN to perform LHC studies.

- ➢SIXTRACK : Single particle 6D tracking code for long term tracing in high energy rings -> complemented with dedicated interaction routines, predicts losses in collimators.
- ➢FLUKA: General purpose particle physics MonteCarlo code used for machine protection, design studies, R2E, activation, collimation -> simulates particle interaction with matter
- ➢SIXTRACK-FLUKA coupling: Sixtrack tracking capabilities utilising the FLUKA particle matter interaction models

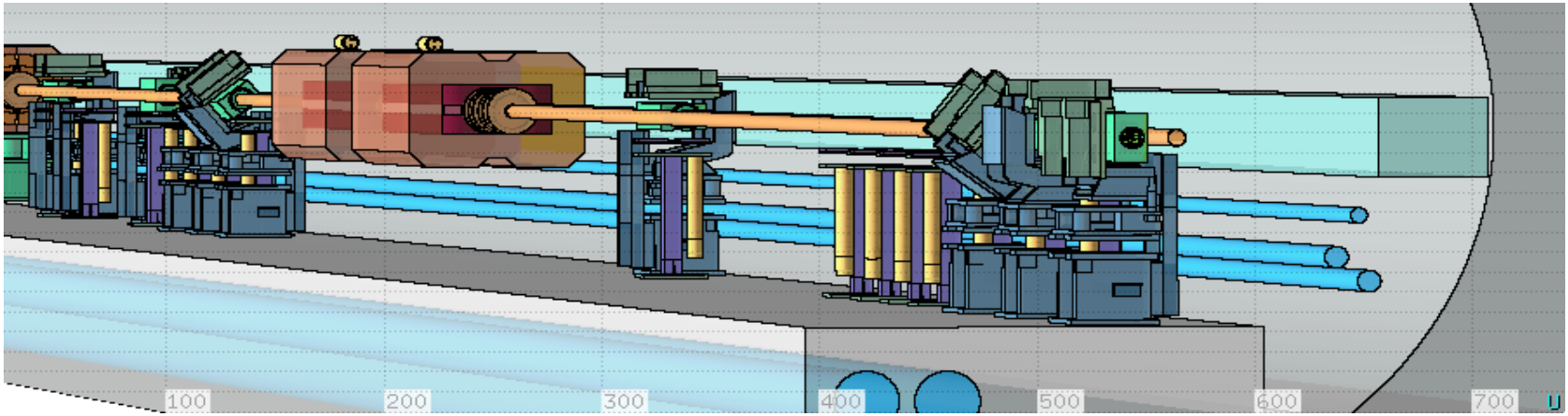


Old Simulation Settings for TCSG.A6R7

- Beam energy: 6.5 TeV – Beam 2
- Nominal collimator settings used in 2015 operation – TCP at 5.5 σ / TCSG at 8.0 σ
- Two materials considered:

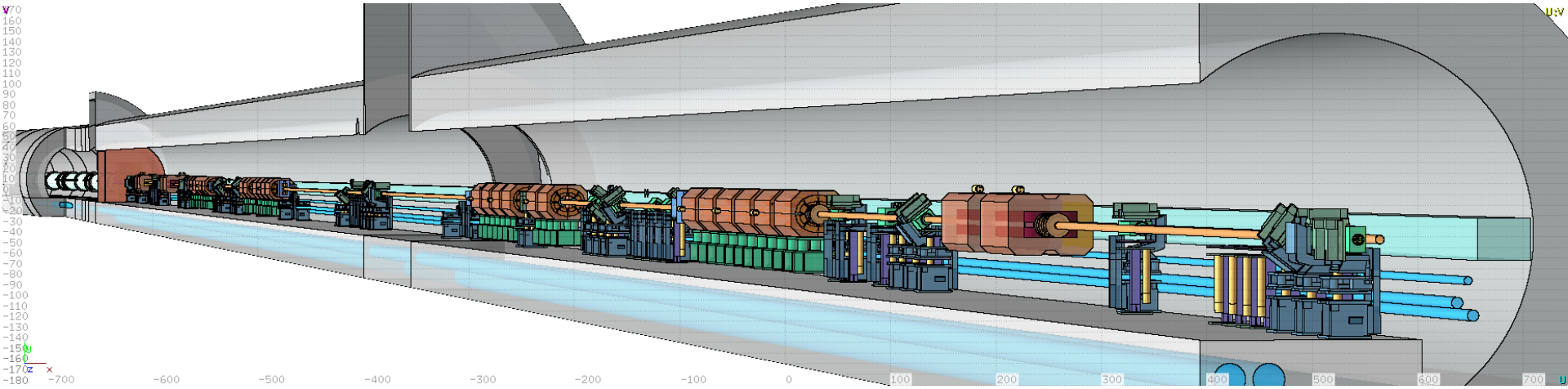
a. Graphite – density: 1.67 g/cm3

b. MoGR6400 – density: 2.48 g/cm3

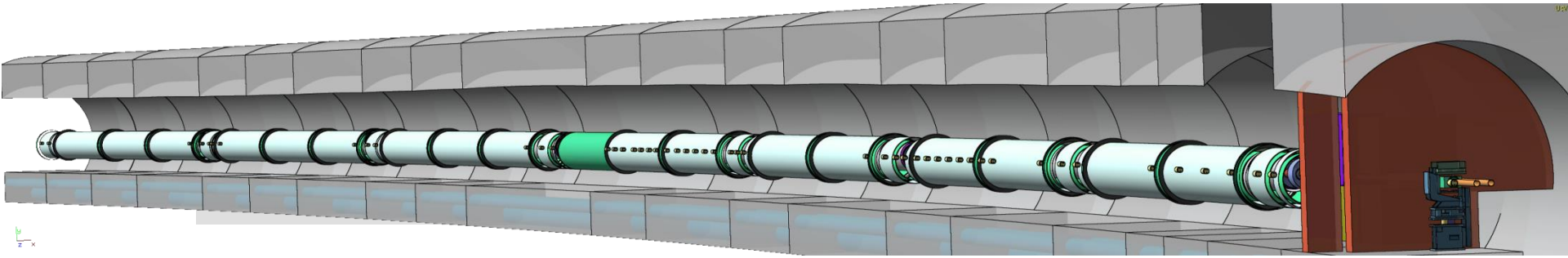


IR7 FLUKA geometry

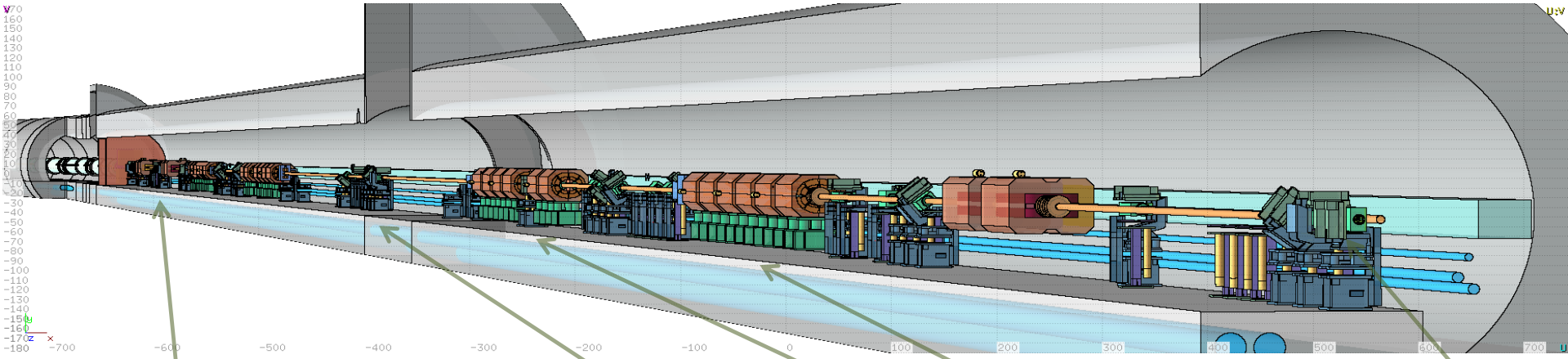
- Long Straight Section

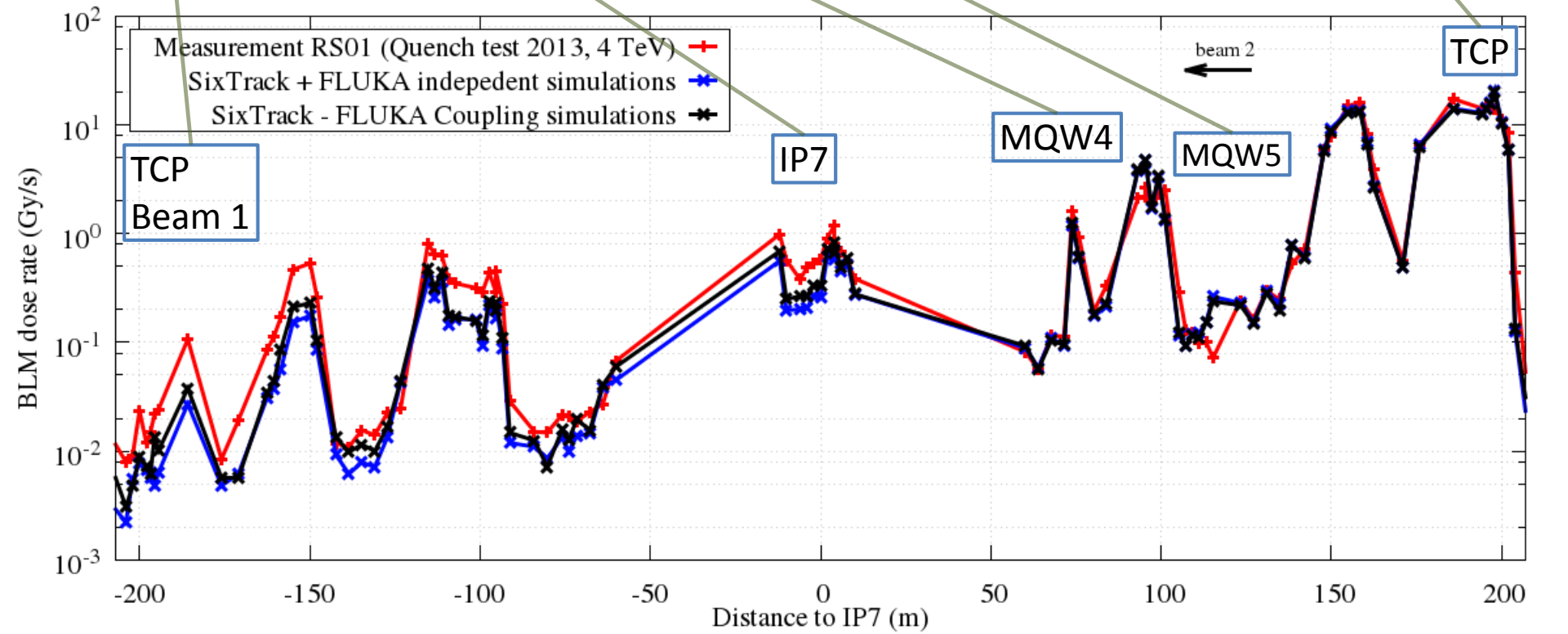


- Left Dispersion Suppressor + Arch up to cell 14

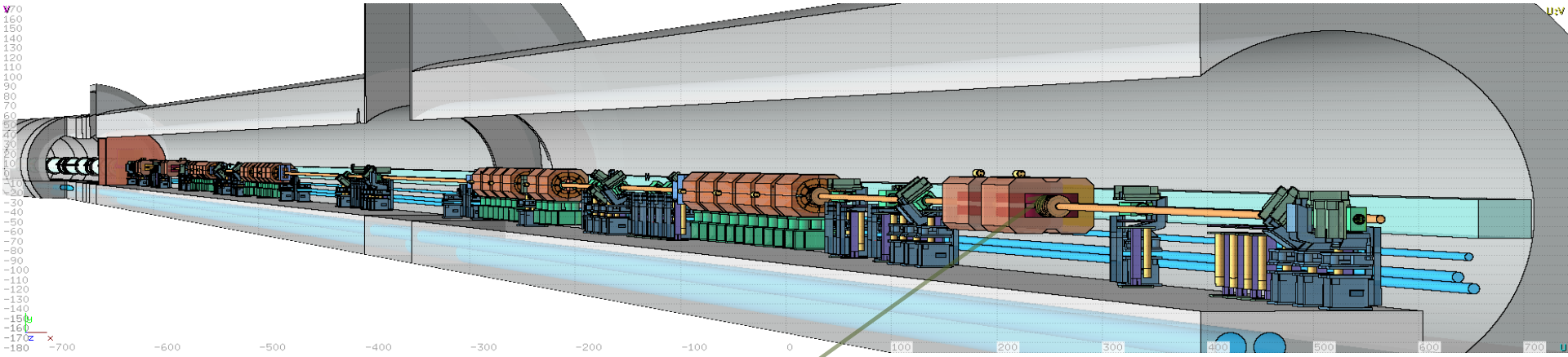


IR7 2013 Collimation Quench Test
FLUKA – Sixtrack Simulations

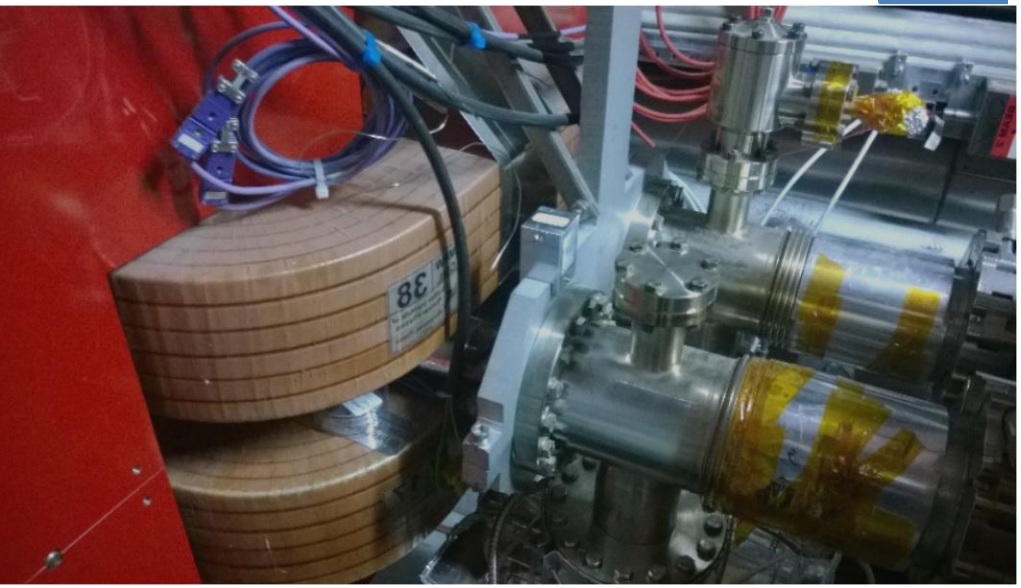


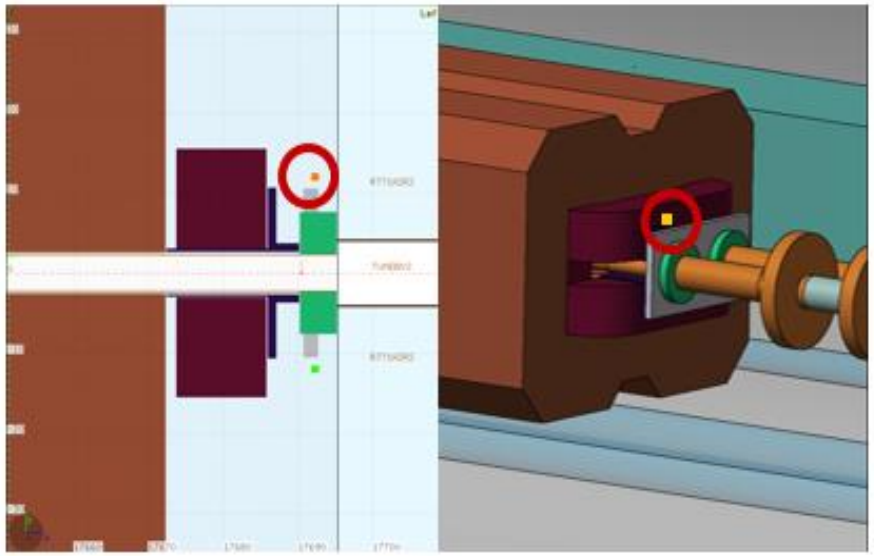


IR7 2015 Evaluating collimation losses



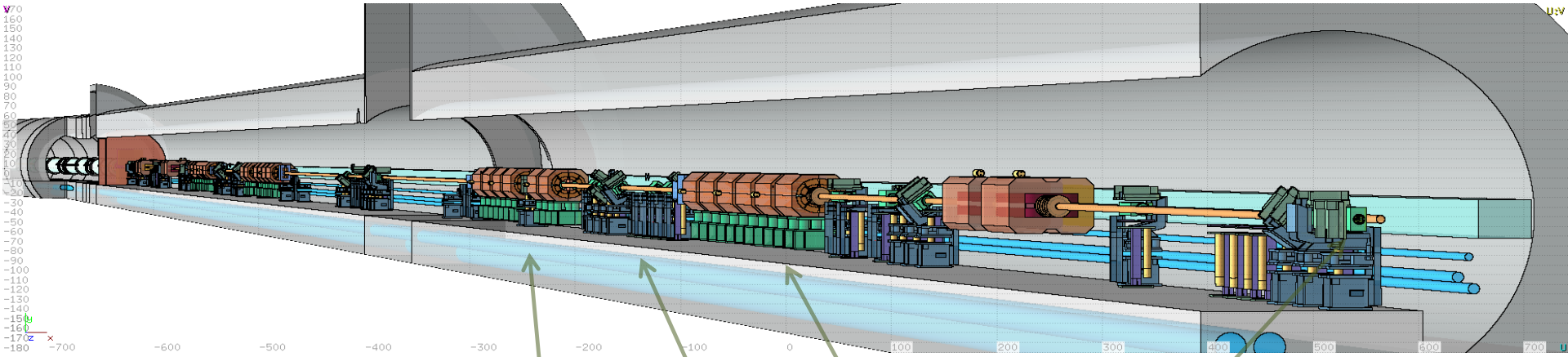
MBW

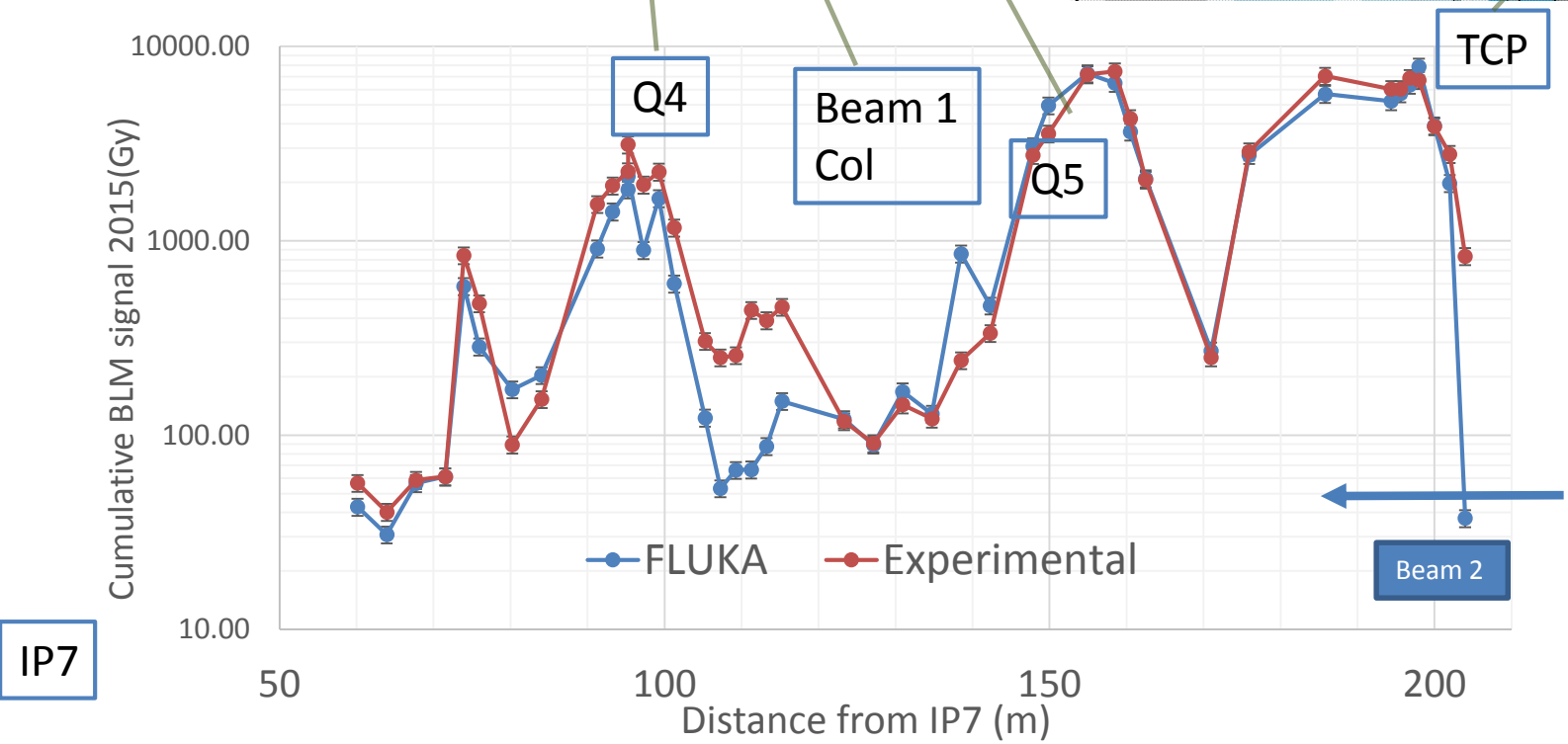




6.5 TeV FLUKA-Sixtrack simulations

IR7 2015 Evaluating collimation losses



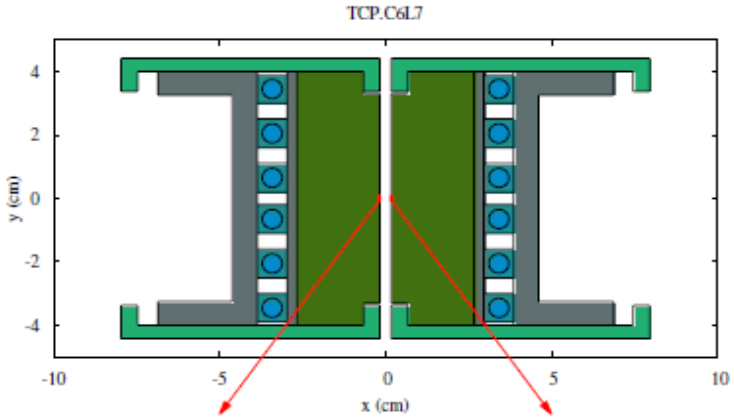


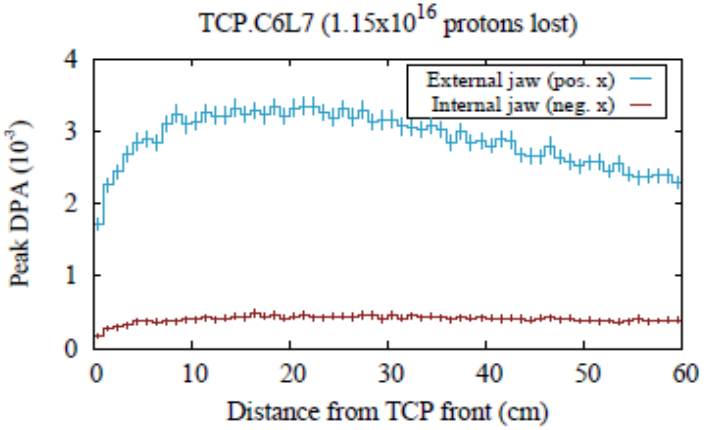
5.5e+14 p*/
~4.3 fb^{-1}

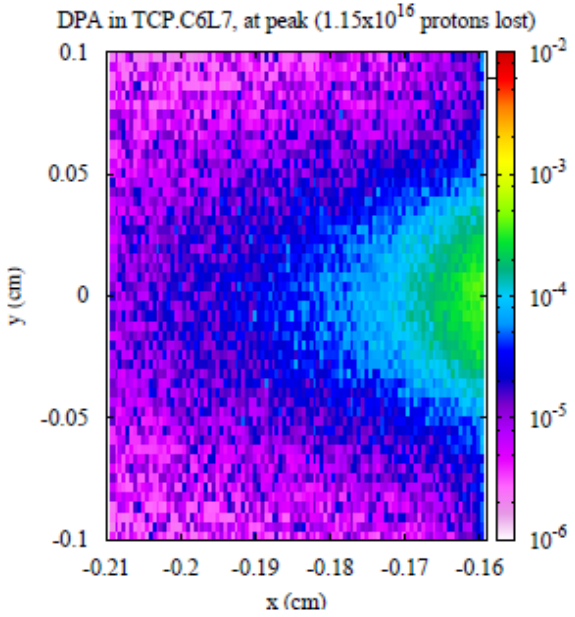
p* =
2015 equivalent
7 TeV proton lost

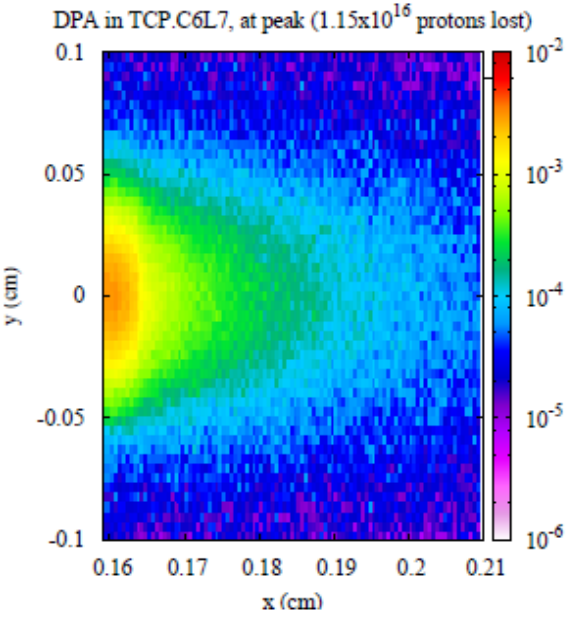
6.5 TeV FLUKA-Sixtrack simulations

DPA in TCP jaws (1.15×10^{16} protons lost) – preliminary results









Assumed E_{thr} (AC150): 35 eV

Max. DPA: $\sim3\times10^{-3}$

Transp. thre.	
photons	100 keV
e^-/e^+	500 keV
neutrons	10^{-5} eV
ions	0.25 keV/nucl
other	1 keV