Energy deposition studies in 11T magnet coils

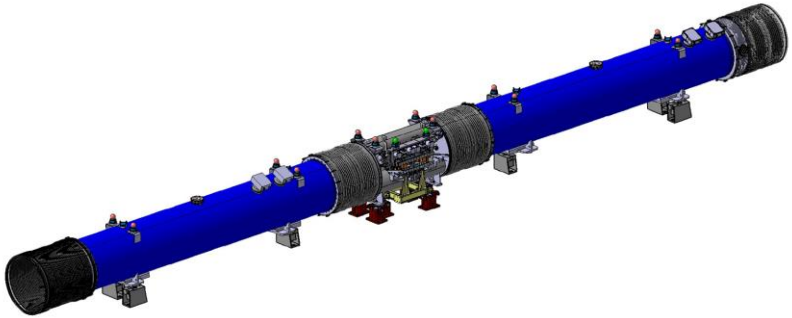
C. Bahamonde, A. Lechner on behalf of the FLUKA team thanking the contributions of R. Bruce, P. Hermes, A. Mereghetti, S. Redaelli

Outline

- **Motivation:** losses in IR7 DS and the need for a collimator
- **Energy deposition studies using FLUKA**
  - Quench risk evaluation
  - Collimator position optimization based on cleaning
- **Study considerations and results**
- **Conclusions**

Motivation: IR7 DS losses and collimation

- In current LHC, **IR7 DS** is the **main bottleneck** in terms of collimation losses both for protons and heavy ions
- In HL-LHC the **stored beam energy** will almost **double** → increased risk of magnet quench and beam dumps → downtime and **reduced machine availability**
    - Mitigation measure: collimators (**TCLD**) to be installed in both IR7 DS to alleviate losses
- Two existing dipoles will have to be removed and replaced by two ensembles of two 11T magnets + TCLD



Quench risk should be evaluated in all superconducting magnets involved

Collimator position should be optimzied for best cleaning balance both in proton and ion runs

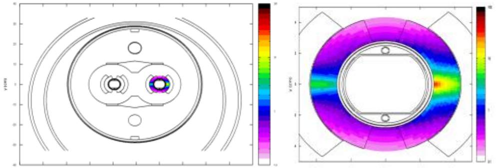
Energy deposition estimates (FLUKA)

Outline

- ★ **Motivation:** losses in IR7 DS and the need for a collimator
- ★ **Energy deposition studies using FLUKA**
  - Quench risk evaluation
  - Collimator position optimization based on cleaning
- ★ **Study considerations and results**
- ★ **Conclusions**

Quench risk evaluation using FLUKA

Power deposition in magnets cannot be measured directly → particle shower simulations (FLUKA) are essential



Information on beam losses
Spatial distribution of the particles (SixTrack)

➕

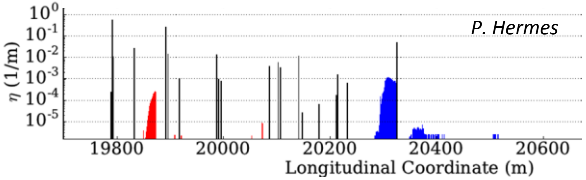
Creating a realistic geometry in FLUKA

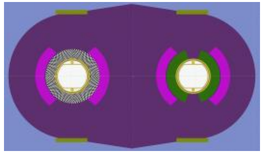
➕

Selecting relevant quantities to calculate
Energy deposition in the coils

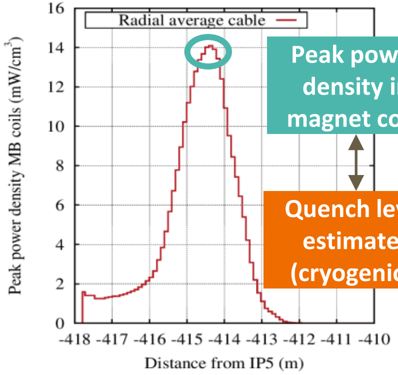
→ **Simulations (recreating experimental conditions)**

FLUKA results: energy deposition→
peak power density in magnet coils





Mesh over the coils
ΔR: 0.2 cm
Δϕ: 2°
Δz: 10 cm

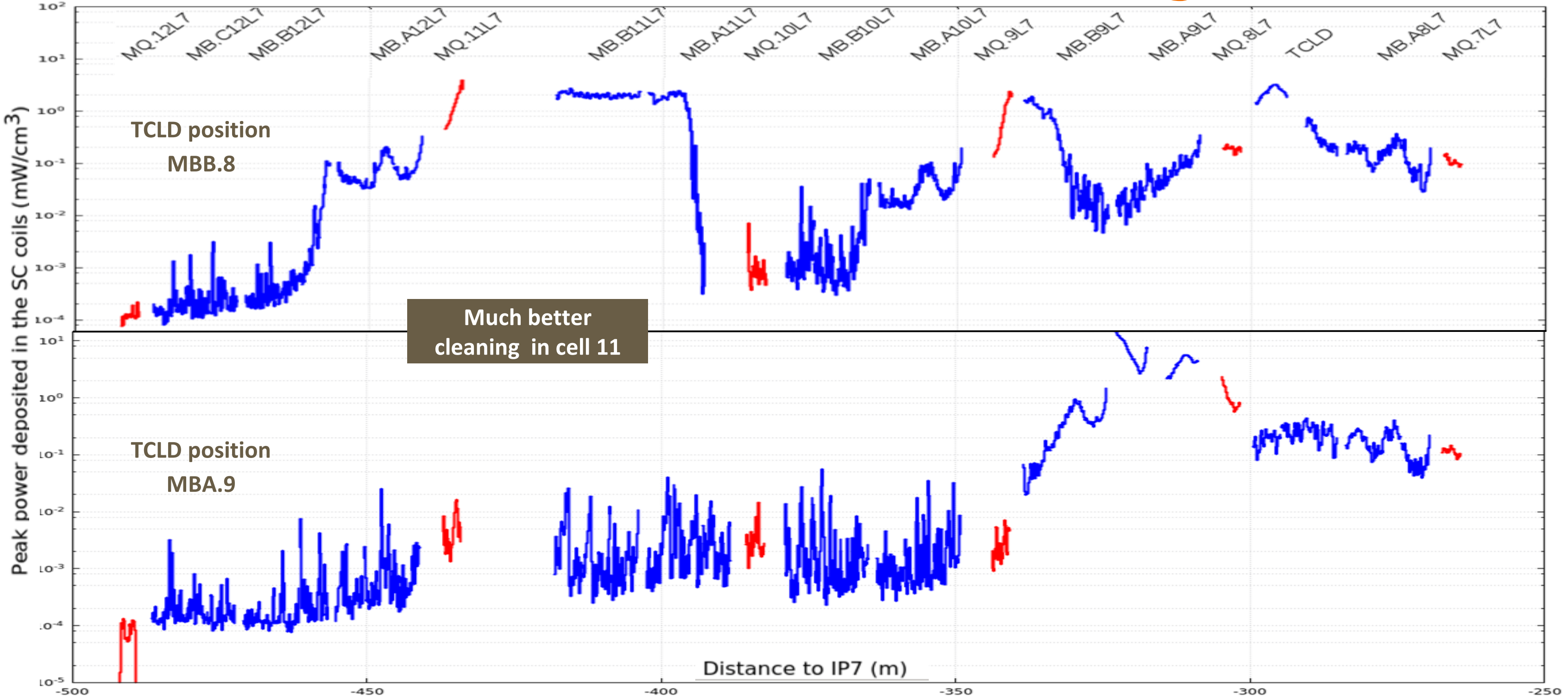


Peak power density in magnet coils

Comparable with

Quench level estimates (cryogenics)

Collimator position optimization using FLUKA



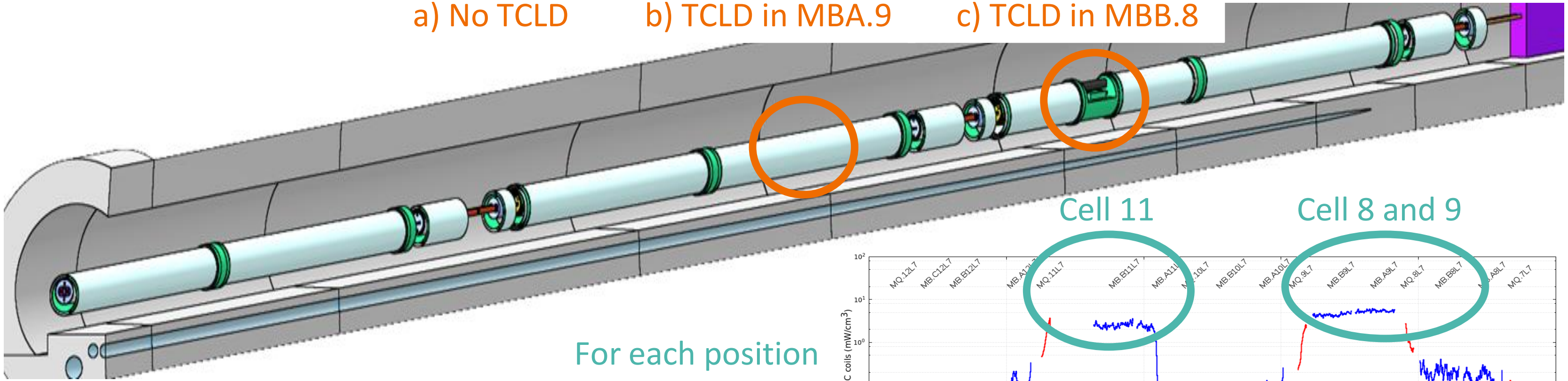
Outline

- **Motivation:** losses in IR7 DS and the need for a collimator
- **Energy deposition studies using FLUKA**
  - Quench risk evaluation
  - Collimator position optimization based on cleaning
- **Study considerations and results**
- **Conclusions**

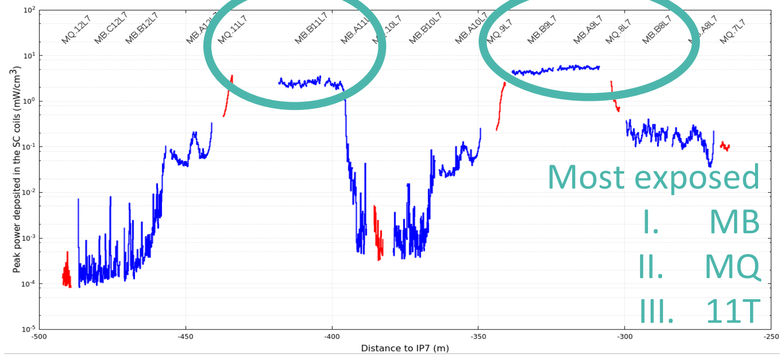
Considered collimator positions

FLUKA geometry of DS: cells 8-11

a) No TCLD b) TCLD in MBA.9 c) TCLD in MBB.8



Cell 11 Cell 8 and 9



For each position and scenario → **peak power density**

Most exposed

I. MB

II. MQ

III. 11T

For each position, two scenarios:

1. Protons
2. Ions

Results

Peak power density for HL-LHC (mW/cm³)										
TCLD position	**PROTONS**					**IONS**				
	Cell 8/9			**Cell 11**		**Cell 8/9**			**Cell 11**	
	MB	*MQ*	*11T*	*MB*	*MQ*	*MB*	*MQ*	*11T*	*MB*	*MQ*
No TCLD	**21**	9.9	-	12	13	**57**	27	-	**57**	36
MBB.8	6.6	8.1	11	8.7	**13**	5.4	15	21	**36**	33
MBA.9	6.0	8.1	**48**	<0.3	<0.3	6.0	3.6	**33**	<0.003	<0.003

Ions: 1248 bunches 2.1e8 ions/bunch
Protons: 8.81e11 p/s assuming 2760b 2.3e11 p / bunch
Beam lifetime: 0.2h → pessimistic
Factor of 3 added → previous benchmarks showed a factor 3 underestimation in DS with respect to BLM measurements

***Quench limit for MB** could be **~20 mW/cm³ for steady state losses at 6.37Z TeV)**

If the quench limit of the 11T is found to be lower than other superconducting magnets, **MBB.8 position would be better for ions**

Outline

- **Motivation:** losses in IR7 DS and the need for a collimator
- **Energy deposition studies using FLUKA**
  - Quench risk evaluation
  - Collimator position optimization based on cleaning
- **Study considerations and results**
- **Conclusions**

Conclusions

Proton and ion runs

- **TCLA settings** can influence a lot the DS peak energy density in Cell 8/9.

Proton runs

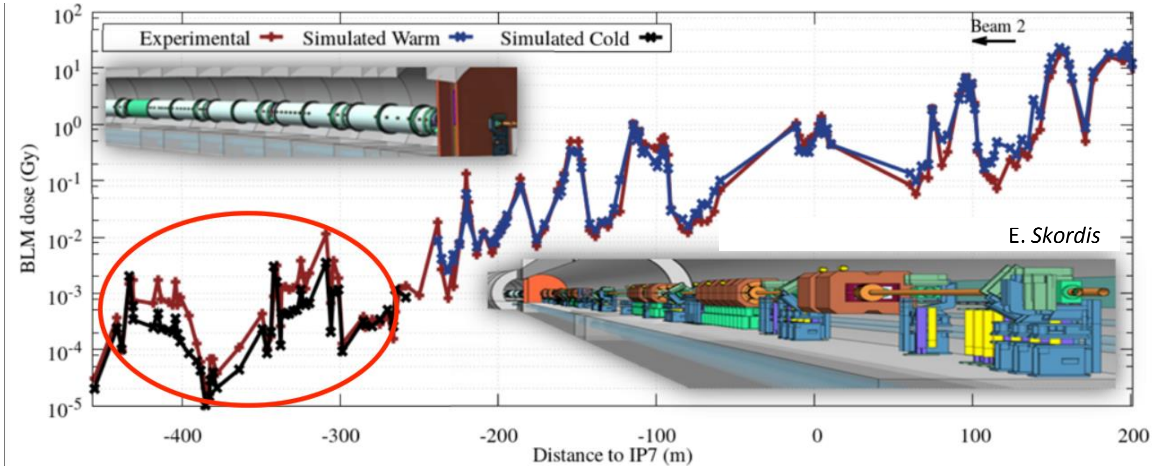
- The TCLD may only help if placed in **MBB.8** (50% reduction in Cell 8/9 and almost no reduction in Cell 11 compared to not having a TCLD).

Ion runs

- **TCP impact parameter** can influence a lot the energy density in the DS.
- When the TCLD is in **MBB.8** position, a factor of 5 reduction could be achieved in cell 8/9 and a 30% reduction in cell 11. When in **MBA.9** position a 40% reduction shows in cell 9 and really good cleaning in cell 11. Both positions are eligible **depending on 11T quench limit**.

Backup

Factor 3: BLM signals benchmark, IR7 quench test



SixTrack + FLUKA producing overall great agreements with experimental BLM signals

- Simulations underestimate measured losses in DS by a factor of 3 → it is proposed to add a factor of 3 to the FLUKA simulation results involving the DS for performance studies to account for this

Simulation parameters

Protons and Pb ions

- **7Z TeV, HL-LHC optics**
- B2, Horizontal case

Collimator materials in FLUKA model

TCP, TCSG in CFC

TCLA, TCLD (when used) in inermet 180

Collimator settings and other details

Ion studies

TCP 6 sigma

TCSG 7 sigma

TCLA 10 sigma

TCLD 14 sigma (when used)

TCSG–TCLA: 1 sigma retraction

TCP–TCLD: 4 sigma retraction

Proton studies

TCP 5.7 sigma

TCSG 7.7 sigma

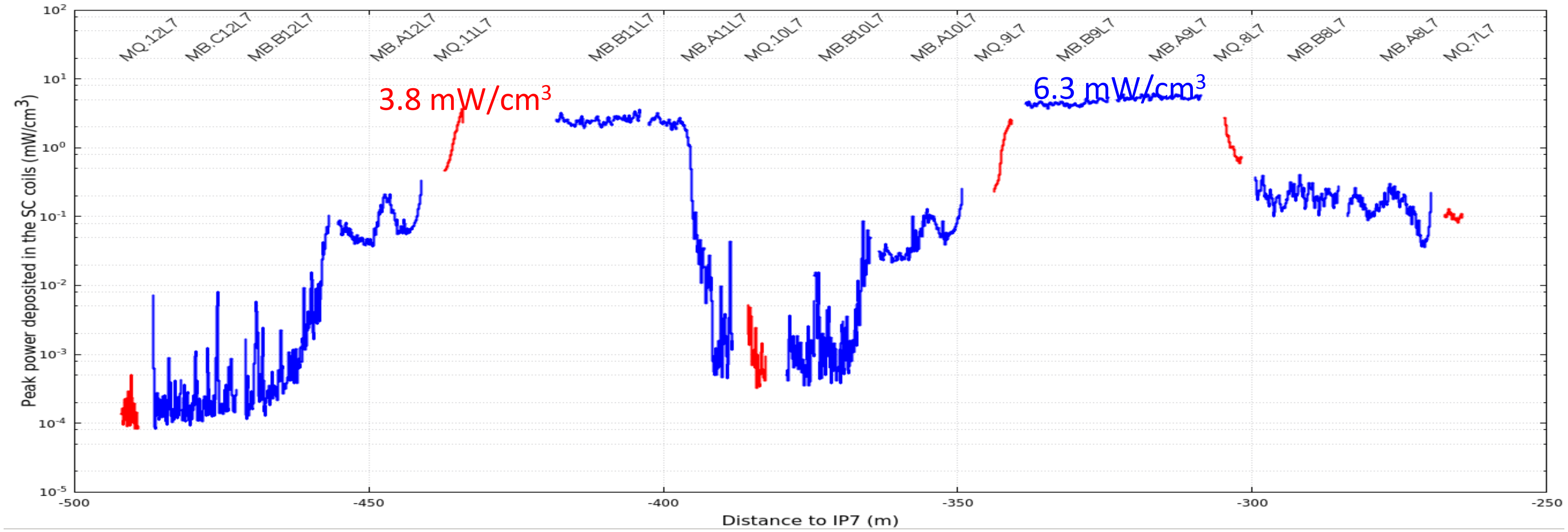
TCLA 10 sigma

TCLD 14 sigma (when used)

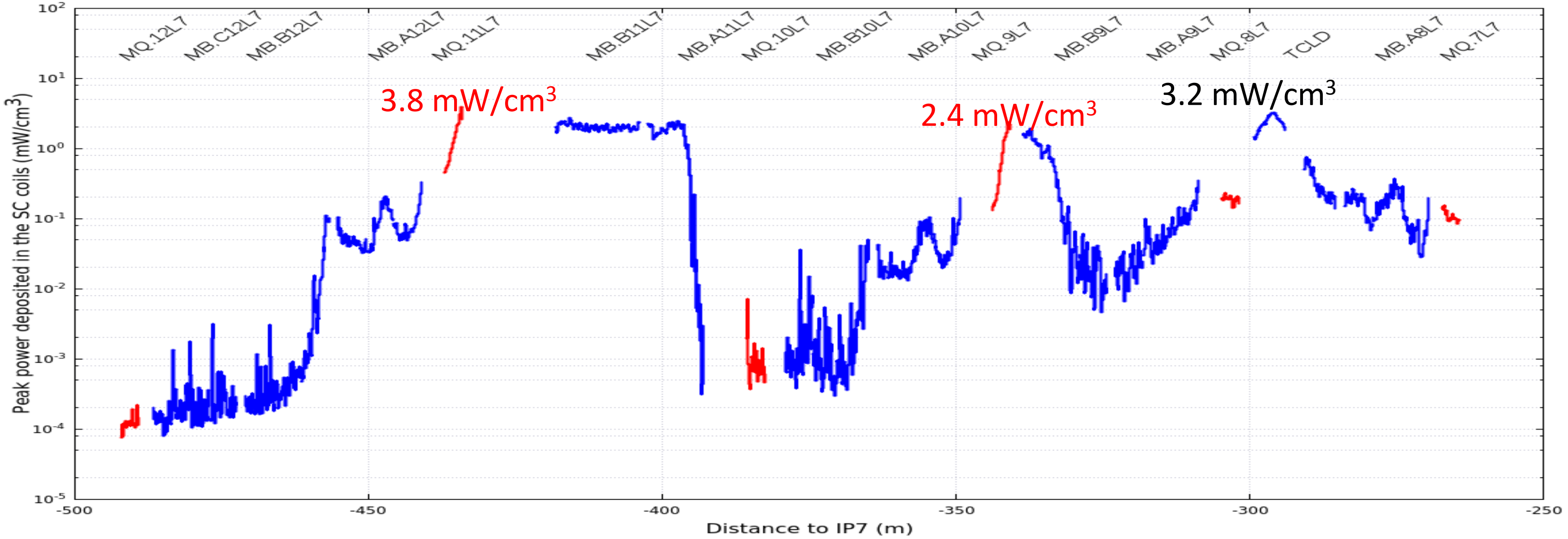
TCP–TCSG: 2 sigma retraction

TCSG–TCLA: 4.3 sigma retraction

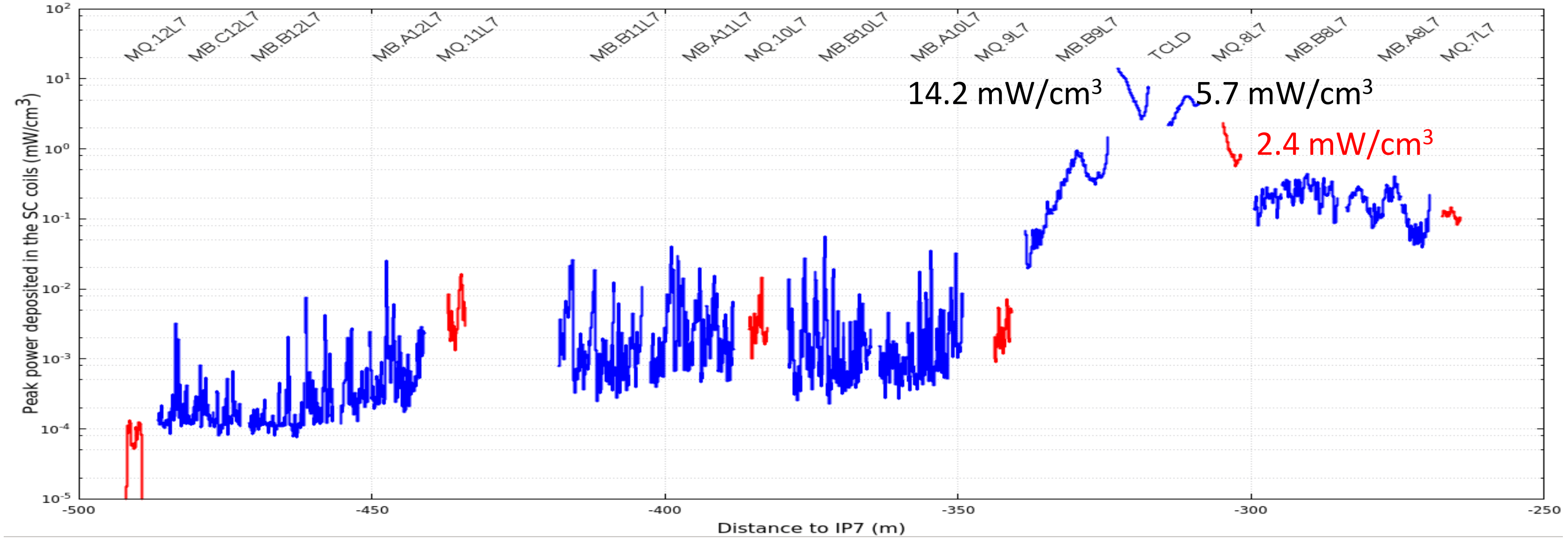
Protons: no TCLD



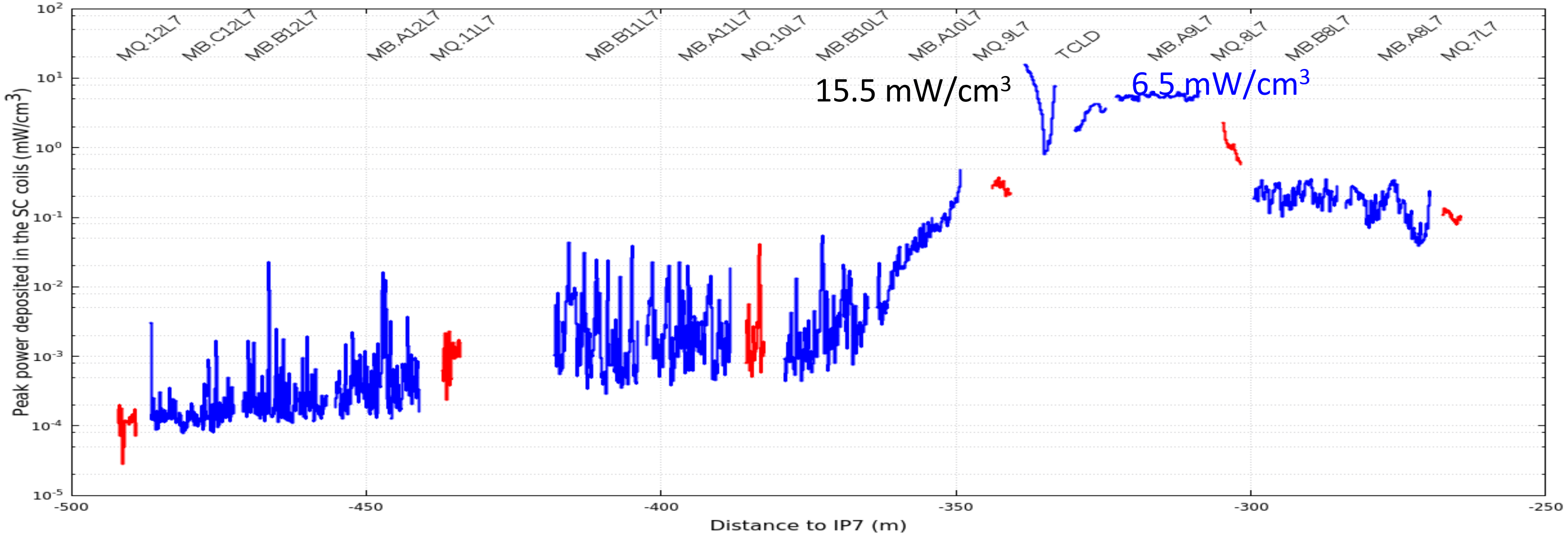
Protons: TCLD in MBB.8



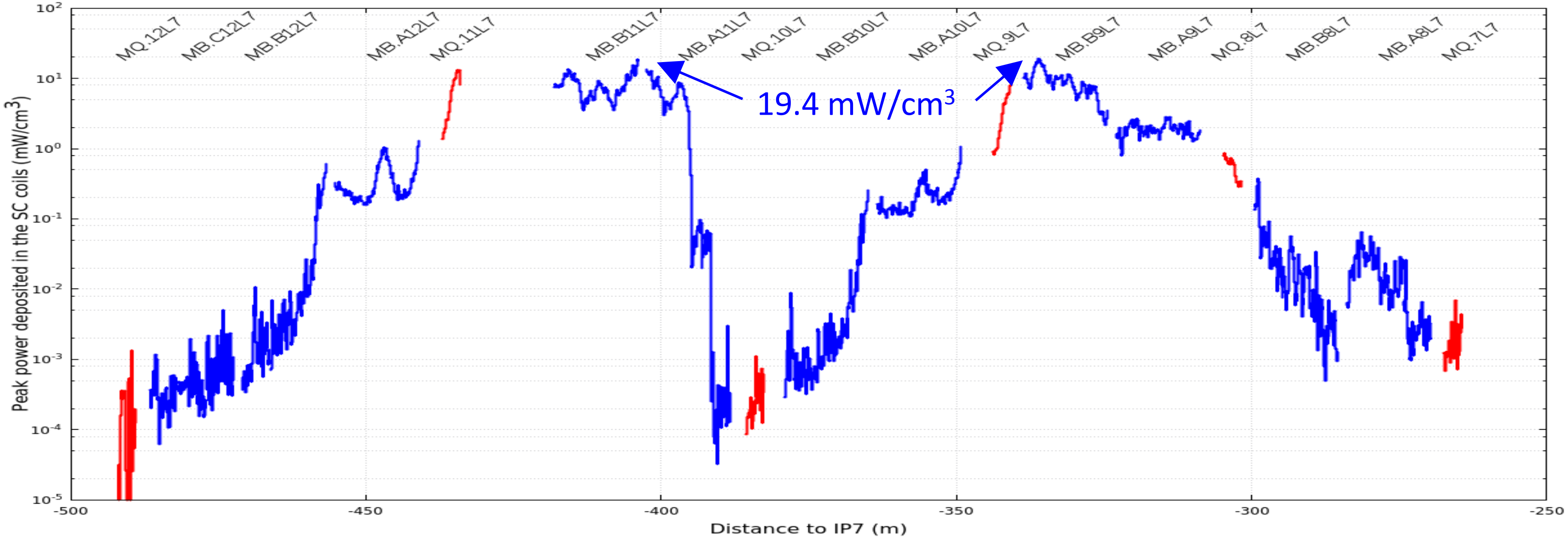
Protons: TCLD in MBA.9



Protons: TCLD in MBB.9

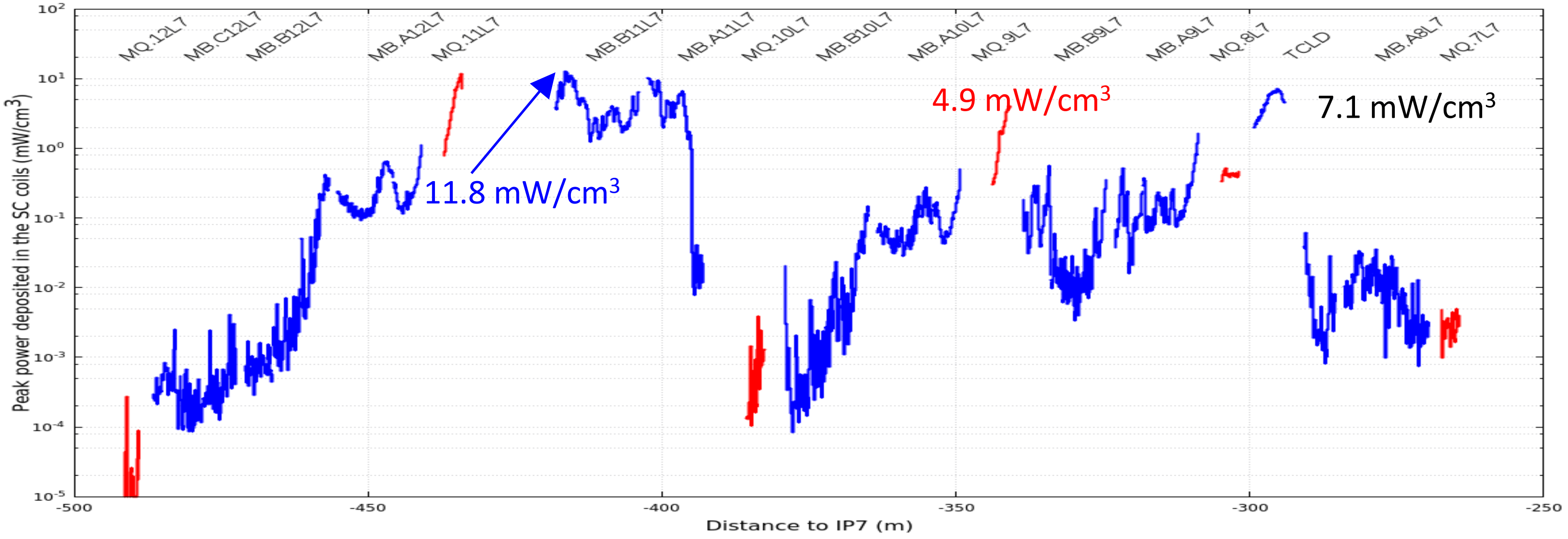


Ions: no TCLD



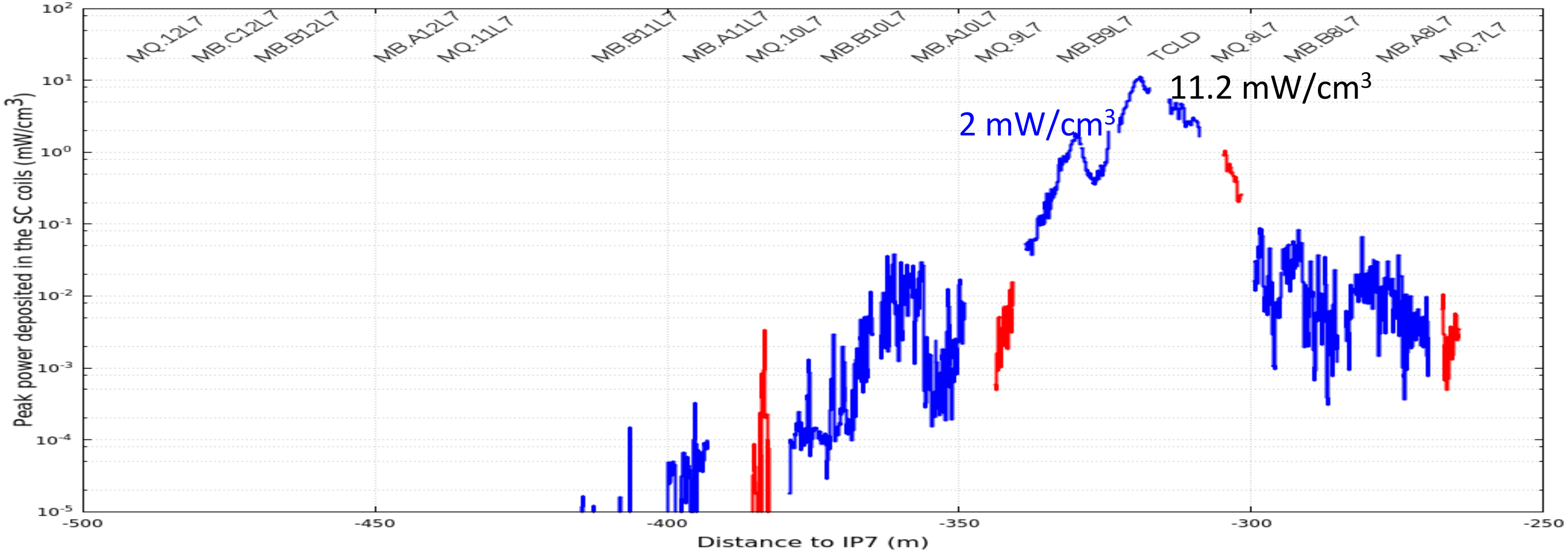
MQ.12L7
MB.C12L7
MB.B12L7
MB.A12L7
MQ.11L7
MB.B11L7
MB.A11L7
MQ.10L7
MB.B10L7
MB.A10L7
MQ.9L7
MB.B9L7
MB.A9L7
MQ.8L7
MB.B8L7
MB.A8L7
MQ.7L7
19.4 mW/cm3
Peak power deposited in the SC coils (mW/cm3)
Distance to IP7 (m)
-500
-450
-400
-350
-300
-250

Ions: TCLD in MBB.8



HiLumi HL-LHC PROJECT

Ions: TCLD in MBA.9



Ions: TCLD in MBB.9