FLUKA studies on the radiation in the Point 5 Q6-Q7 area: Roman Pots, TCL6 and RR

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on behalf of the FLUKA team

Acknowledgement for the valuable input: M. Deile

Summary from previous meeting

- **TCL4** aperture at **15 σ** makes no significant difference **respect to 10 σ**
  - with an even larger aperture, TCL4 would start to not intercept neutral debris:
    - it could be considered not a big issue for D2-Q4, however a greater gradient could be expected in Q7
- TCL6 is not necessary to protect Q6 or Q7 when RP are operated
- However, **TCL6 installation** might be advisable to substantially reduce losses in **Dispersion Suppressor**, independently from RP operation
- If TCL6 is eventually installed in Point 5, it should be installed also in **Point 1**

maximum power ~ 0.5 mW/cm3

power > 1.0 mW/cm^3 are reached

few slides extracted from that presentation have been added as backup material

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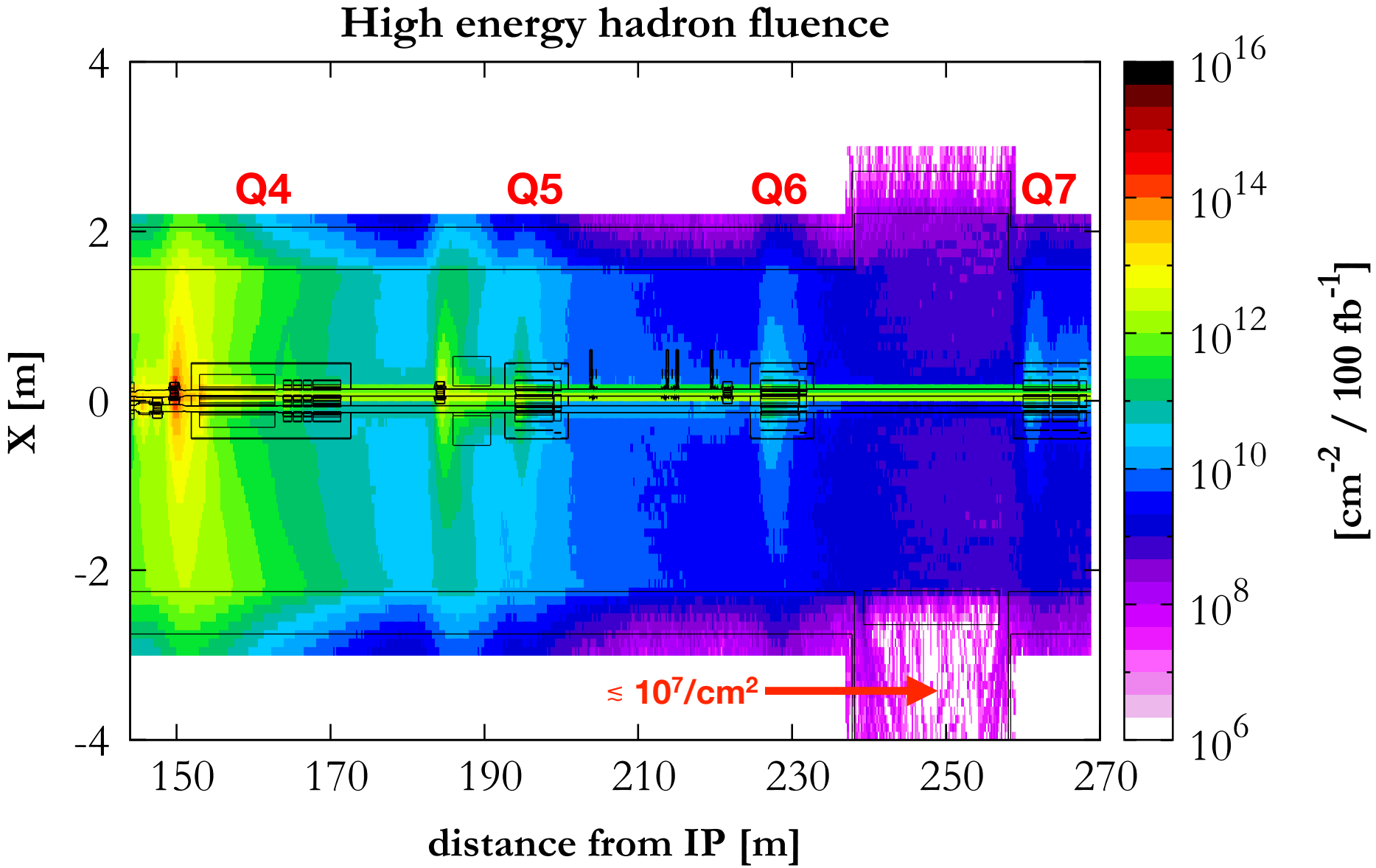
HC-LJ-EC-0033 for the infrastructure installation of TCL6s approved in October
Nonetheless it is stated that the installation will proceed if "*it is proved that they would bring benefits to the post-LS1 operation*"

few slides extracted from that presentation have been added as backup material

Outline

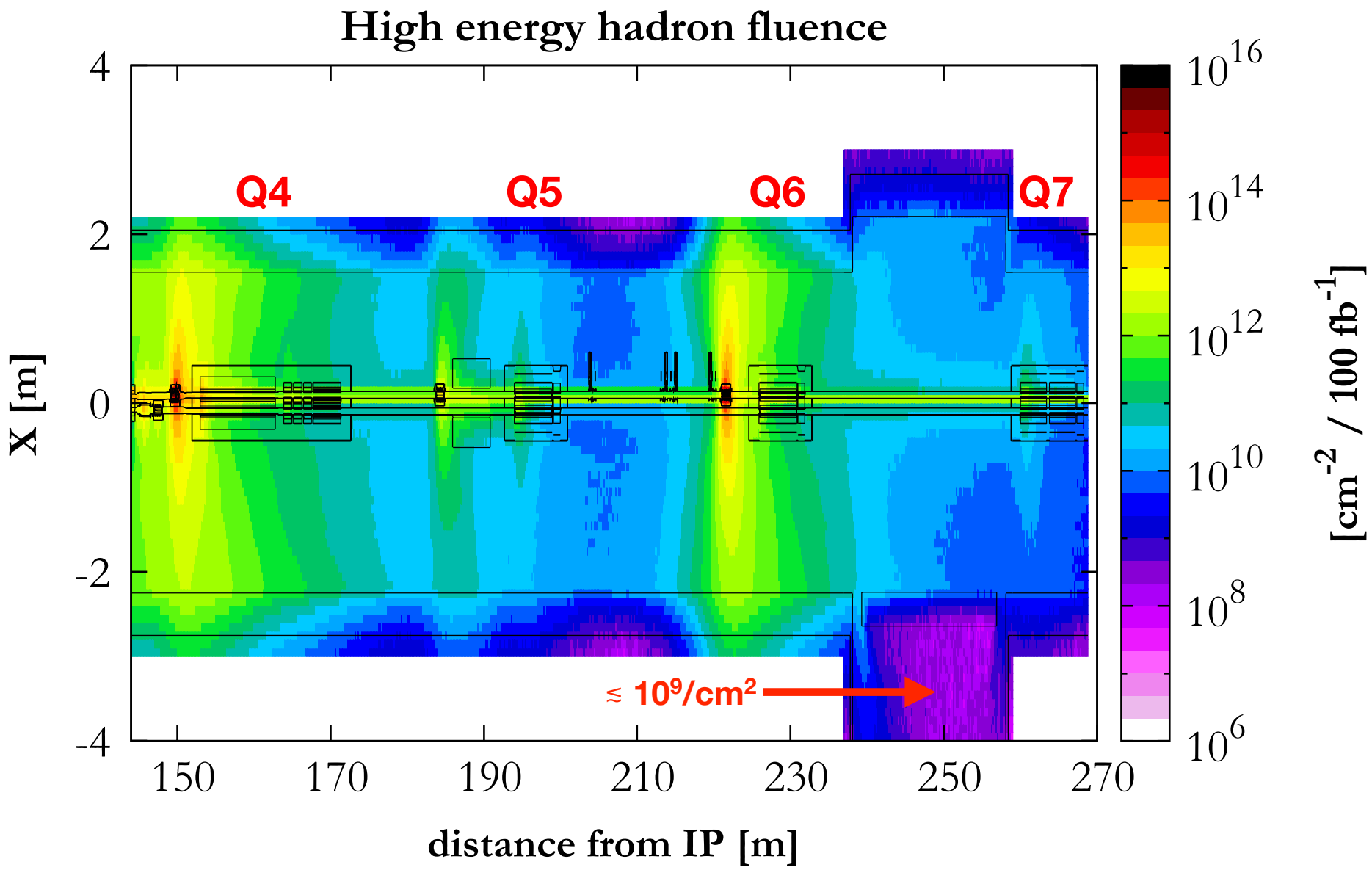
- Nominal LHC operation
  - evaluation TCL6 impact on RR
  - possible mitigation with an iron Maze (like P7)
- Comparison with 2012 data
  - RadMon
  - TOTEM rate
  - BLM

Beam-line w/o TCL6: collision debris

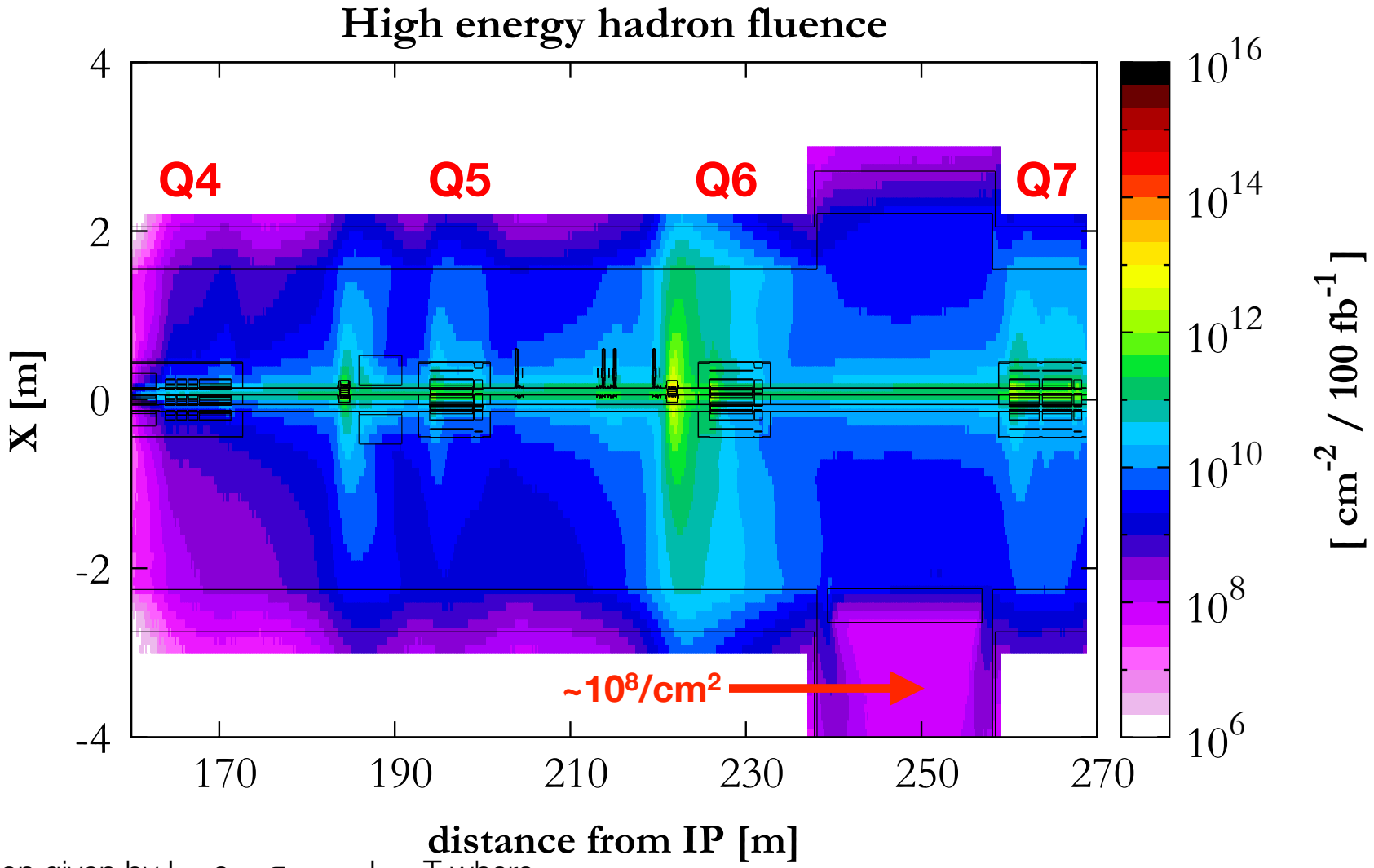


Nominal LHC optics; proton-proton collision at 14 TeV c.o.m. energy (85 mb)
High energy (>20 MeV) hadron fluence at beam height (±20 cm)

Beam-line with TCL6: collision debris



Beam-gas interaction @7TeV with TCL6

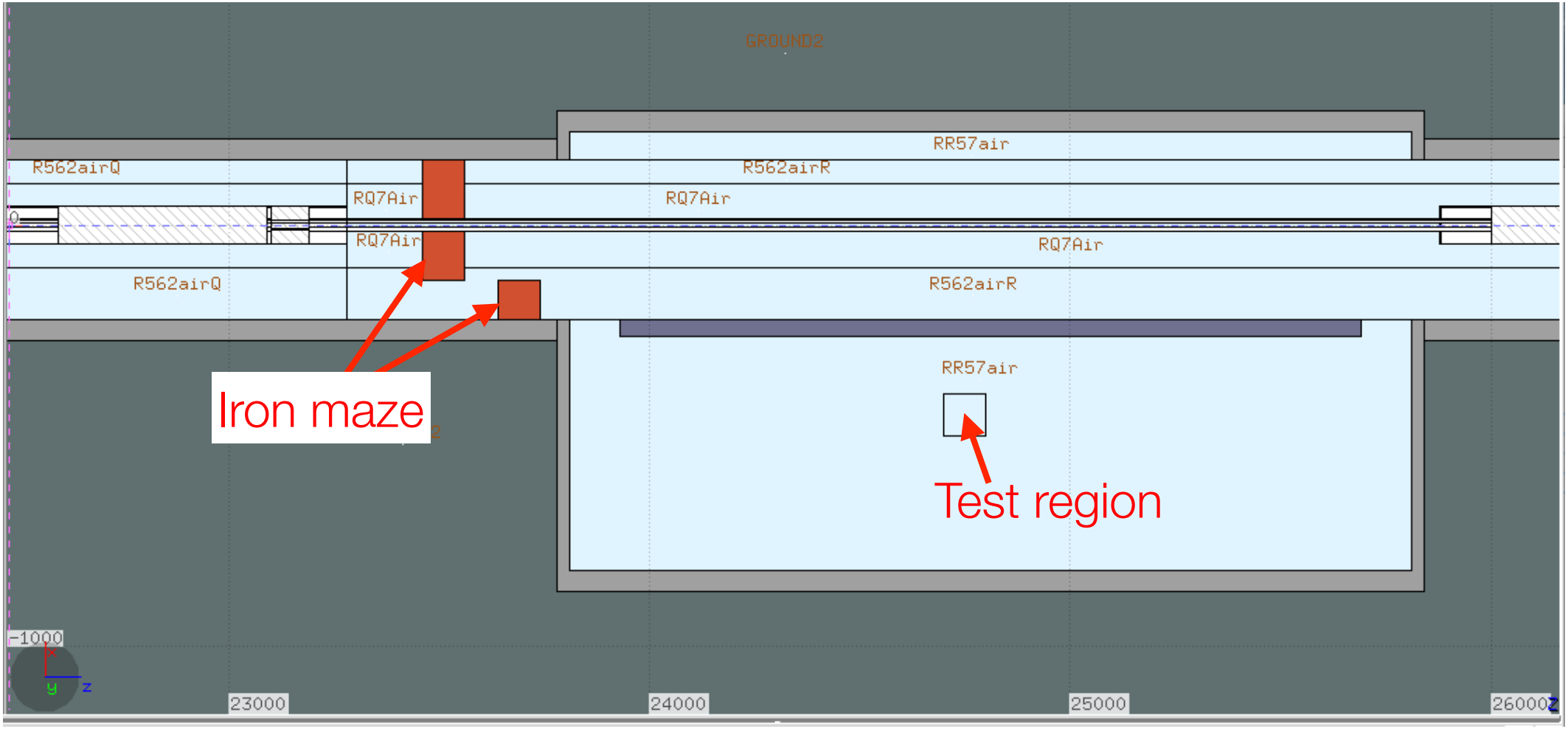


- normalisation given by $I \times \rho \times \sigma_{p\text{-}H2} \times L \times T$ where
  - $I = 0.581$ A/e
  - **$\rho = 10^{15}$ molecules/m^3**
  - $\sigma_{p\text{-}H2} = 2 \times \sigma_{p\text{-}p} \simeq 76.5$ mb,
  - $L = 108.9$ m (from 160 m to 268.9)
  - $T = 100$ fb^{-1} / 10^{34} cm^{-2} s^{-1} = 10^7 s

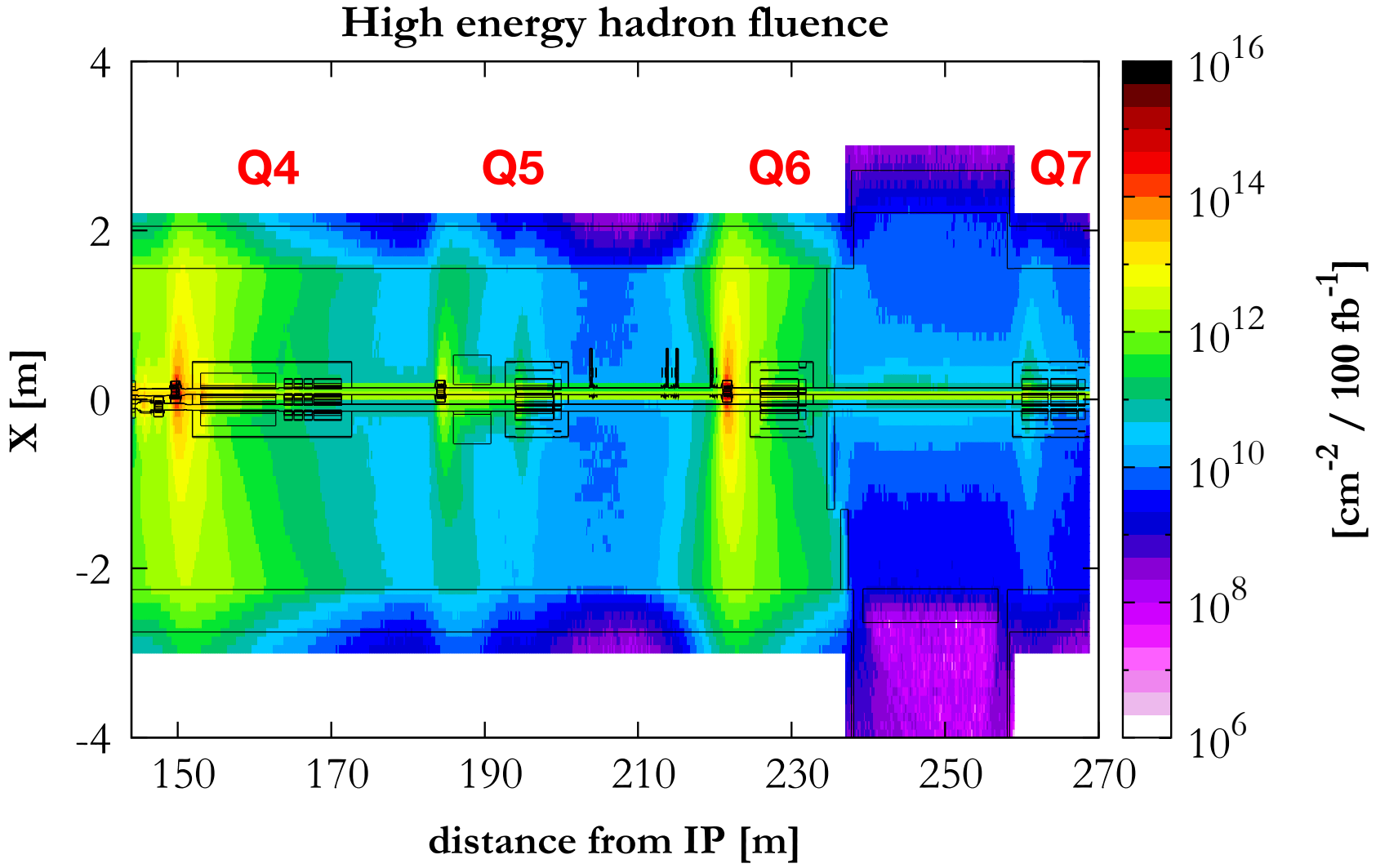
contribution to RR fluence from beam gas is lower than the one from collision debris by a factor of few

Iron Maze mitigation effect

IRON MAZE (like Point 7)

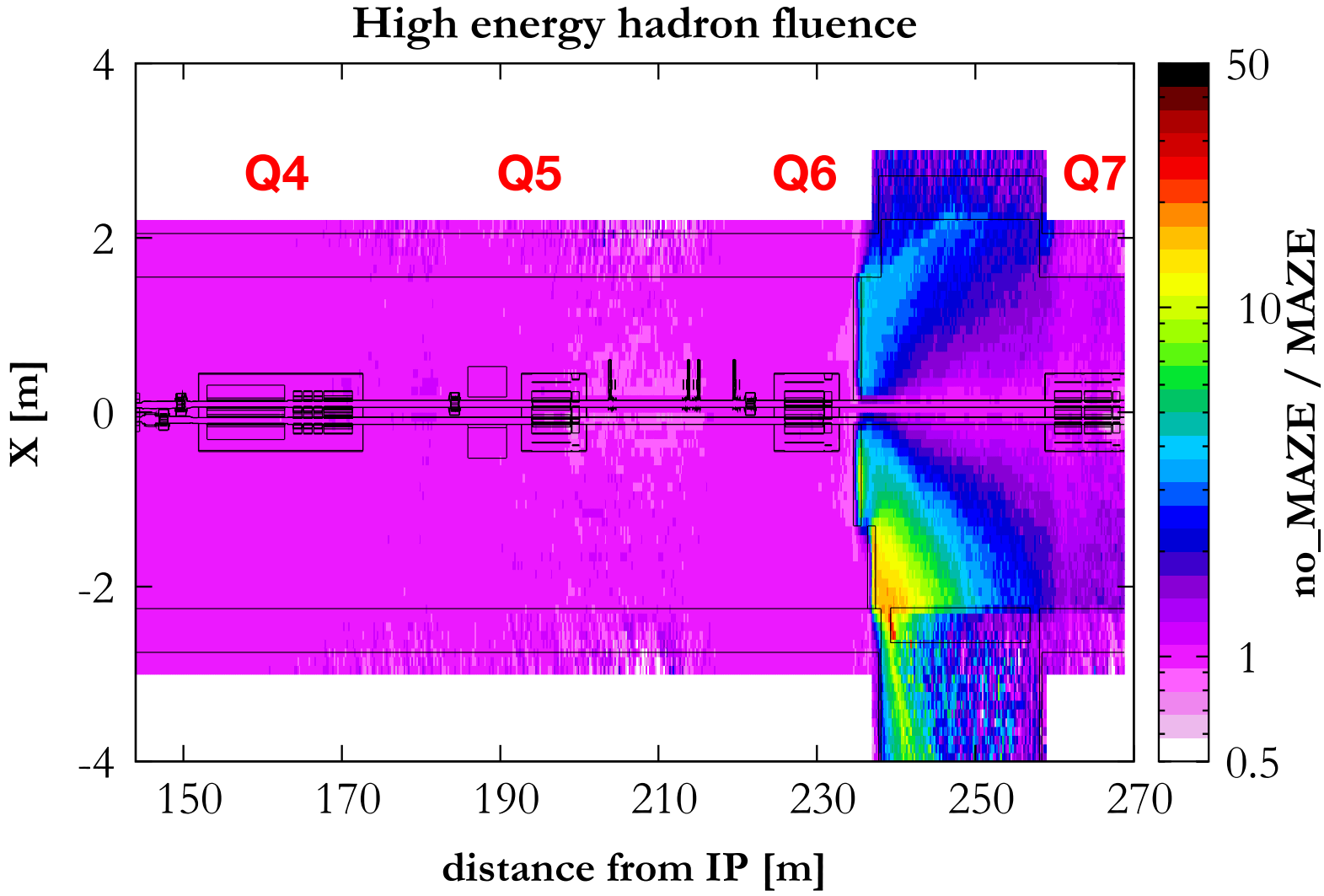


Effect of the maze in the RR



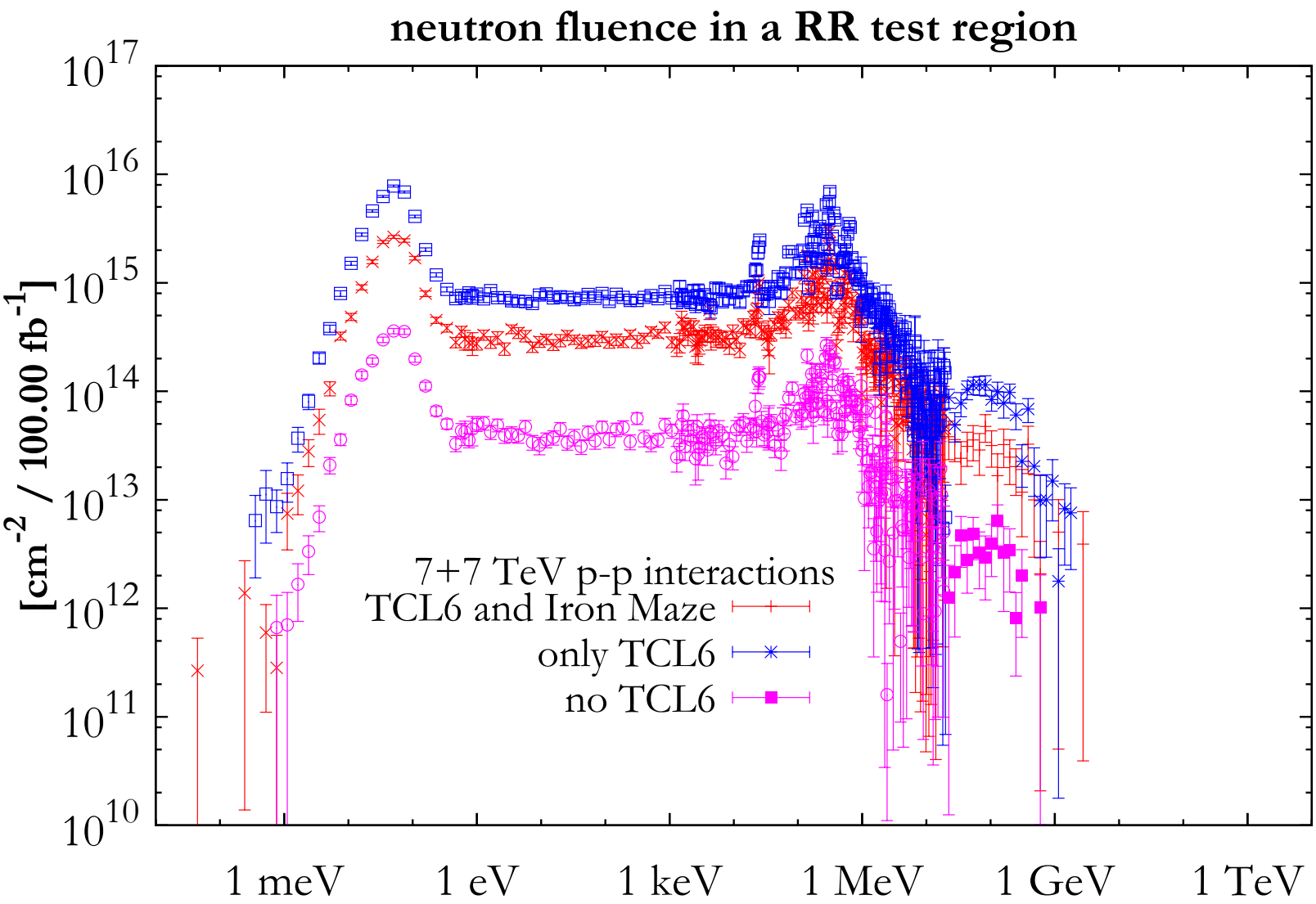
the maze effectiveness is limited

Maze effectiveness



Iron maze protection rather limited in large part of the RR

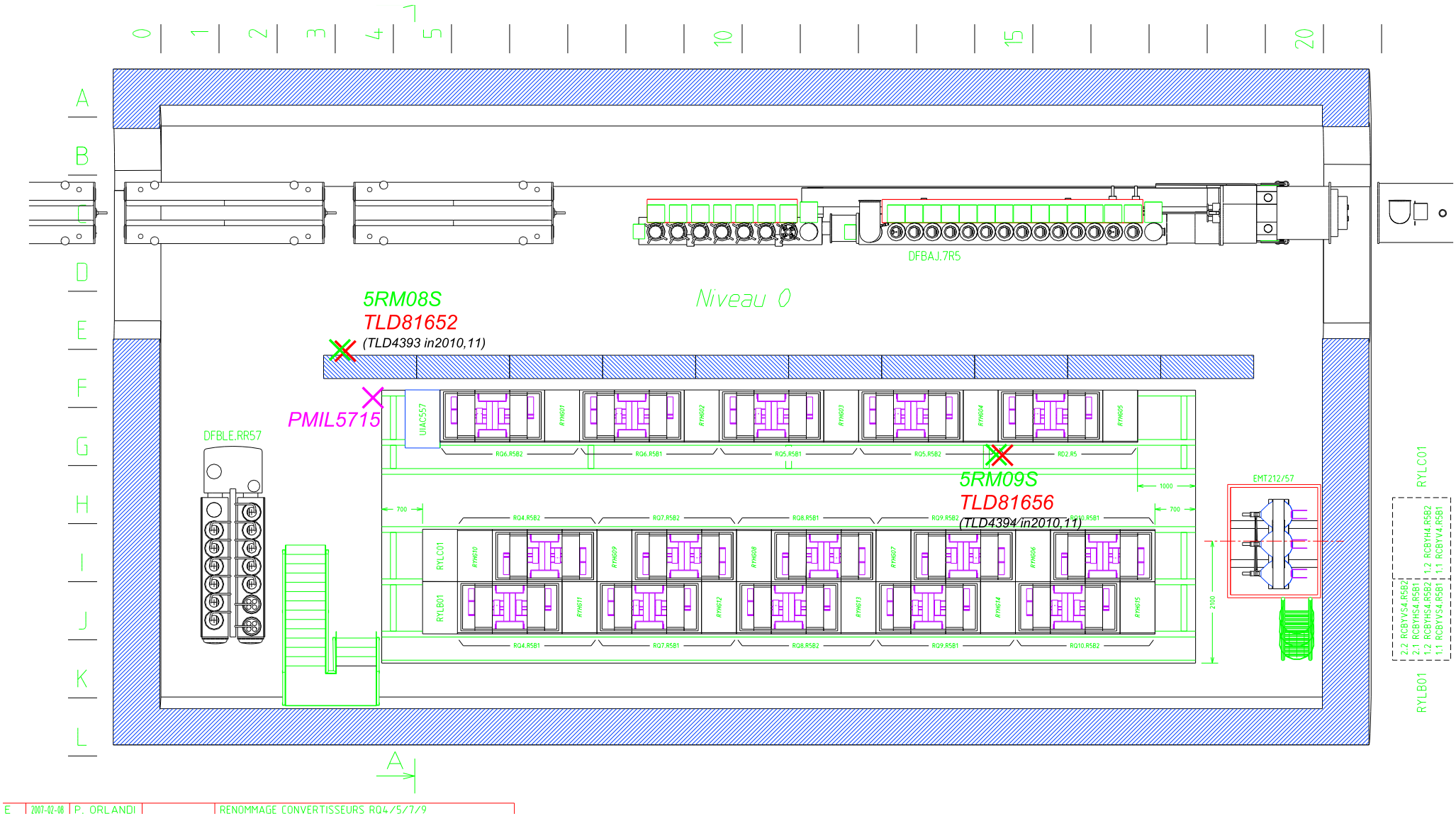
Neutron fluence in a test region



The limited moderation effect of the maze seems not to justify its installation

2012 operation:
RadMon, TOTEM rate, BLM

RADMON position in RR57

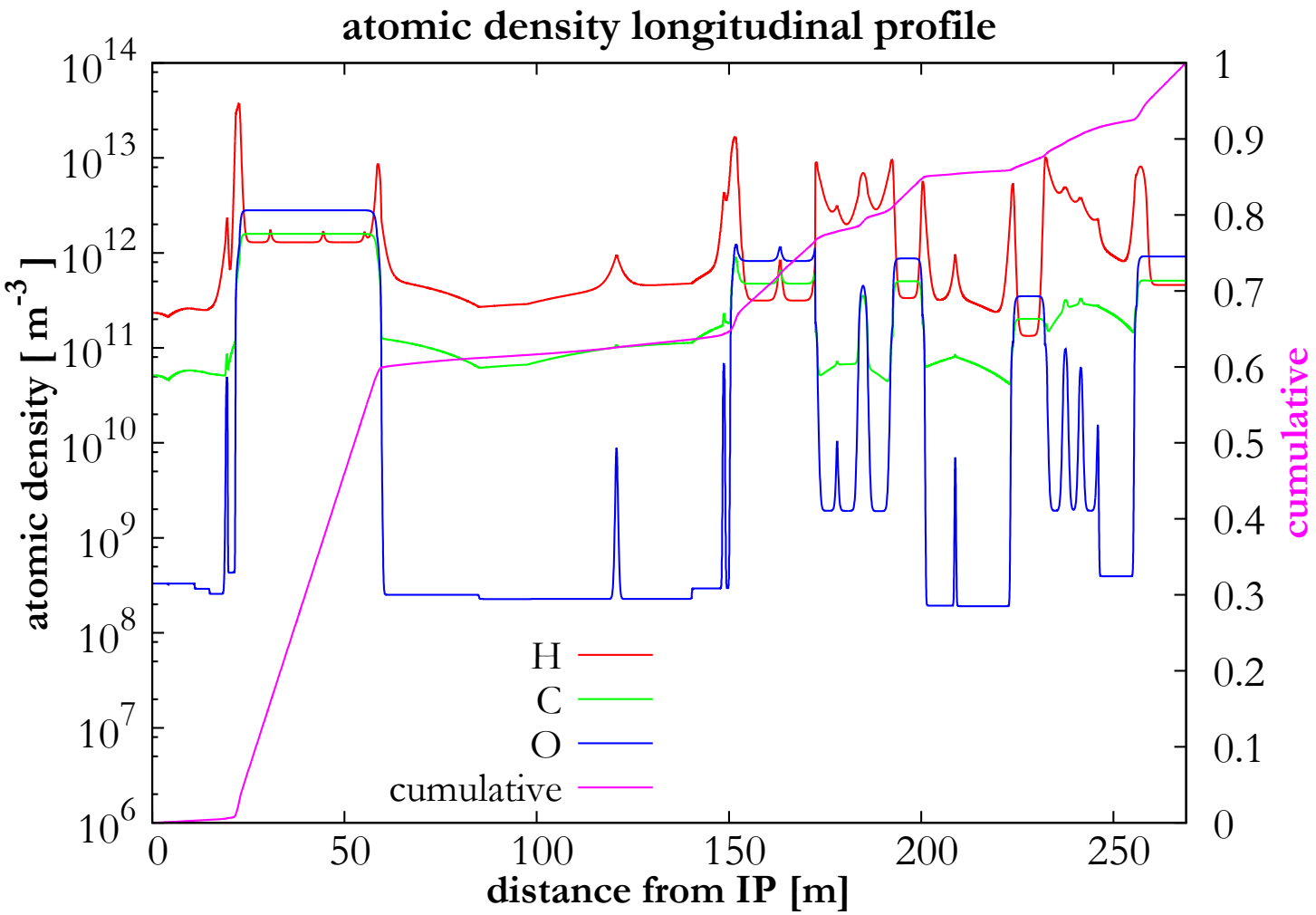


Normalisation for 4 TeV operation

- **collision debris normalisation factor** =
  $\mathscr{L}_{Int} \times \sigma = 23.26\ fb^{-1} \times 75\ mb$

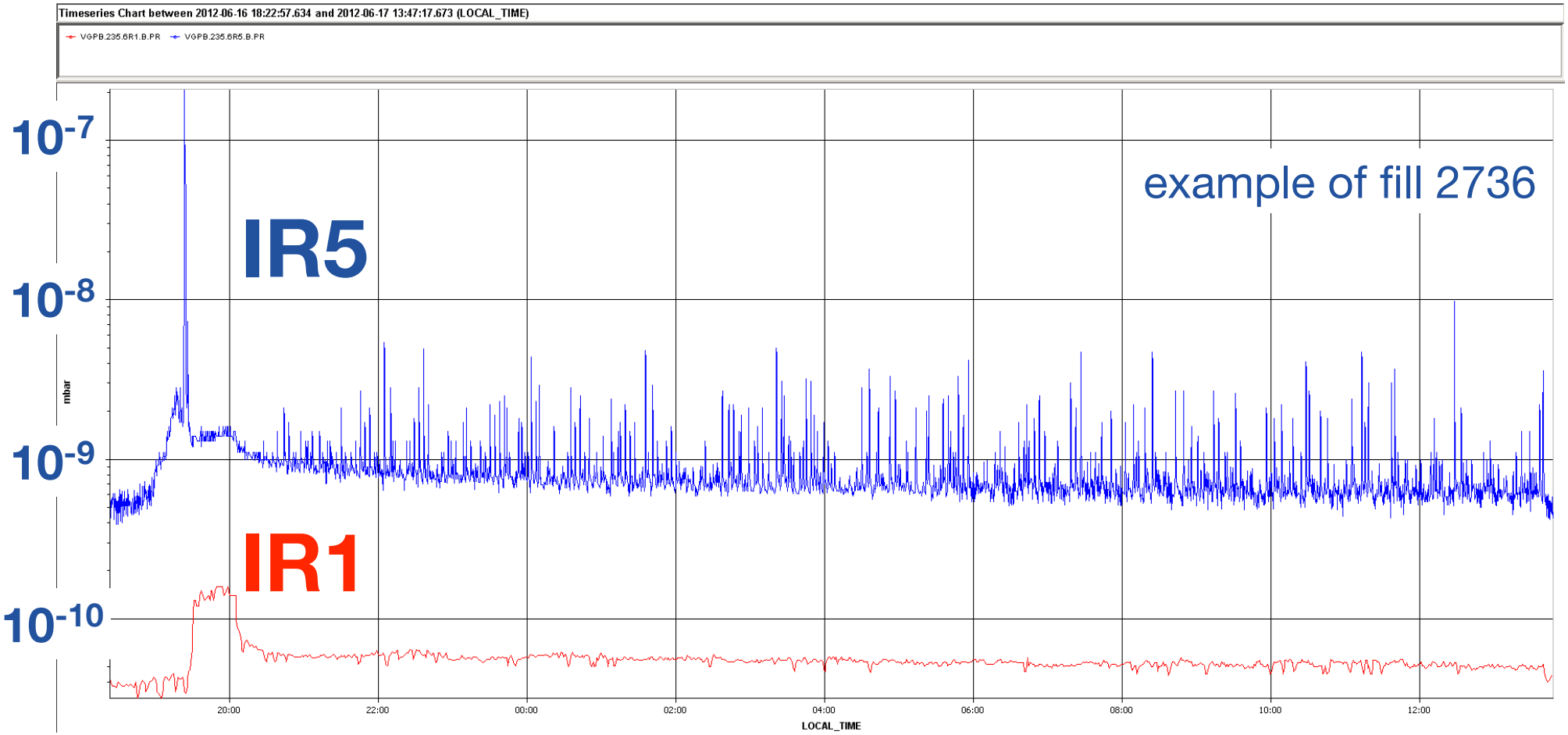
- **beam-gas normalisation factor**
  (limited to the contribution during stable beam)
  = <bunch population> × #bunches × v × T_{SB} × P_int
  where
  - <bunch population> is computed from luminosity
  (assuming ε = 2.4 μm, β* = 60 cm)
  - T_{SB} = 73 day 10 hrs 52 mins
  - frequency = 11.2455 kHz
  - P_int(σ, ρ(s))

Beam gas profile



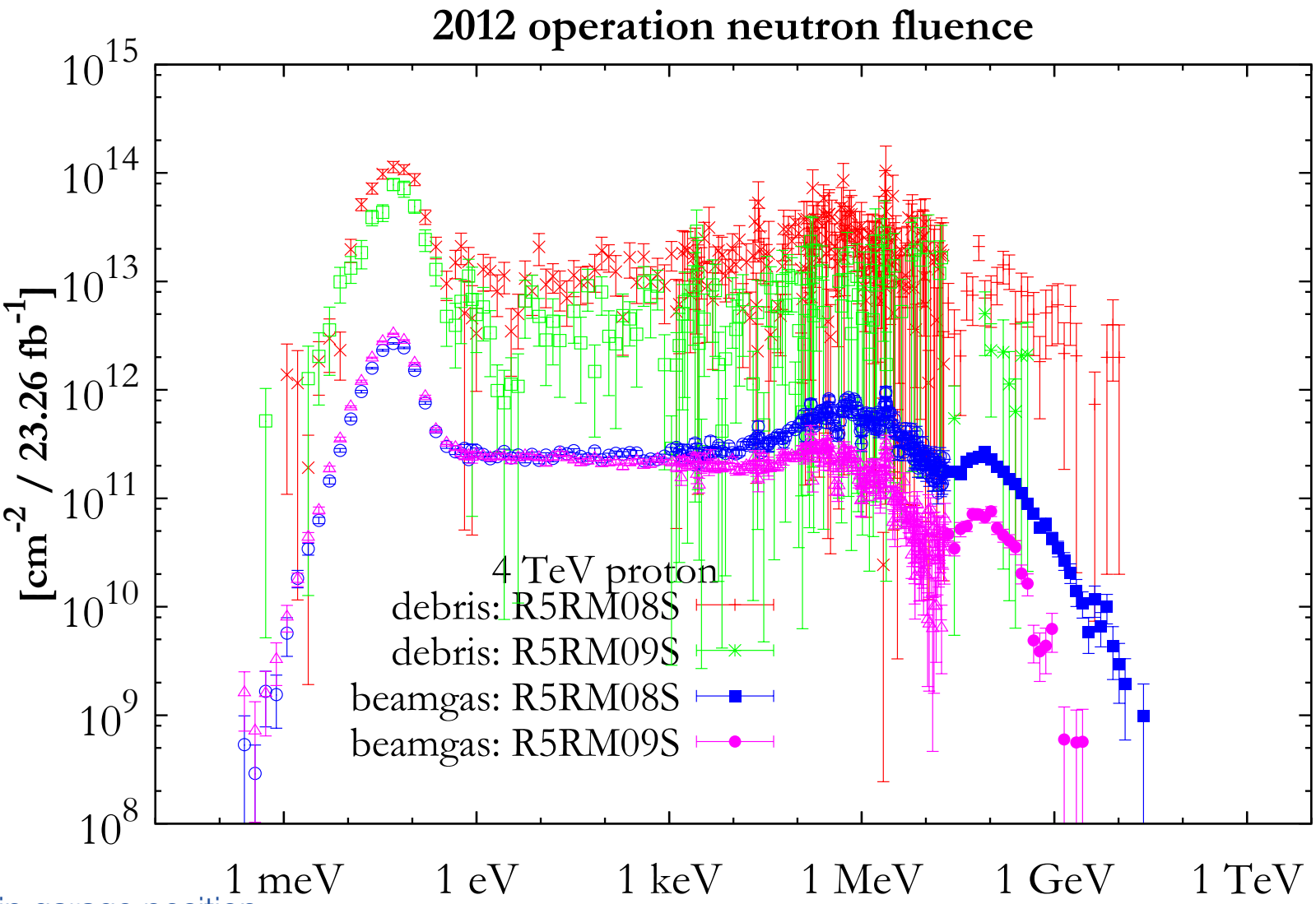
Computed by G. Bregliozzi for **Point 1**
Fill 2736 - 16/06/2012 - 17:20 - 1380 Bunches - 4 TeV - 373 mA
(input data refers to the first 5 minute when the CCC declares Stable Beam)

Caveat: IR5 vacuum quality in sector 5-6



Unperturbed vacuum in 6R5 and 6L5: $5 \times 10^{-10} - 10^{-9}$ mbar
in 6R1 and 7R1 (ALFA): $3 - 5 \times 10^{-11}$ mbar

2012 operation with standard settings



Roman Pots in garage position
TCL5 half gap = 3.55 mm

With gas density peaks of the order of 10^{13}-10^{14} molecules/m^3, beam-gas contribution seems negligible

Contribution from collision debris only

	Hadron > 20 MeV [cm^{-2}]	
	RM08S	RM09S
FLUKA	6.1×10^8	3.0×10^7
DATA	4.56×10^8 (256 upsets)	4.32×10^7 (25 upsets)

Normalised at total integrated luminosity in 2012 operation

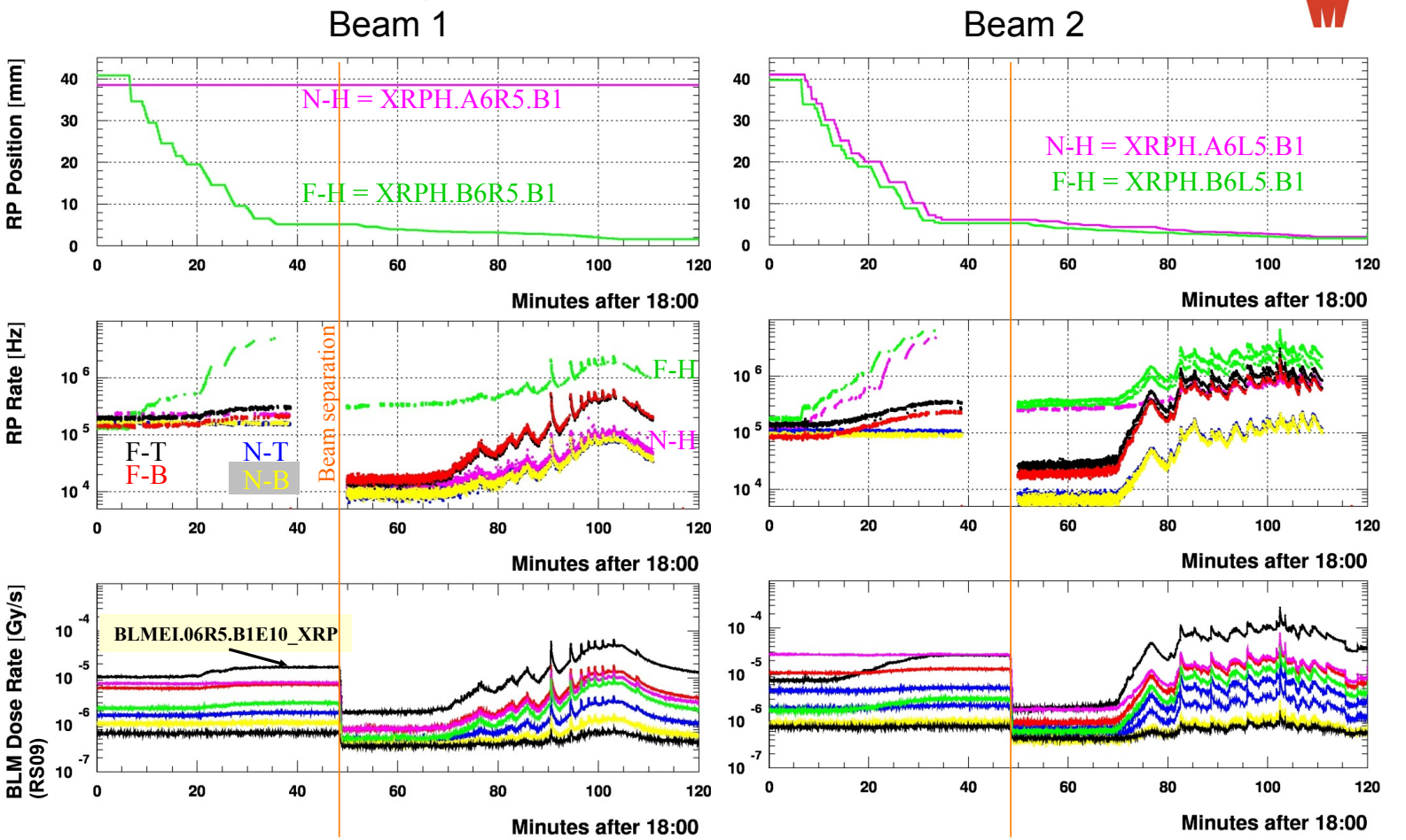
The agreement is within 30%!!!

TOTEM operation: fill 3288

Insertion 15 November: Overview

TCL5 already at 60 sigma = 21 mm

Reference time: 15 November 2012, 18:00 h



Mario Deile – p. 24

After the beam separation $\mathscr{L} \sim 2.5\ 10^{33}\ cm^{-2}\ s^{-1} \rightarrow 10^{32}\ cm^{-2}\ s^{-1}$

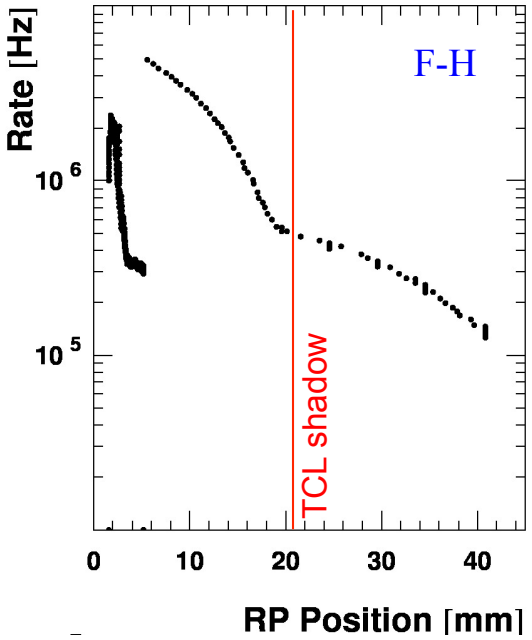
In the simulation, the case where only F-H station was operated is considered

Roman Pot rate

15.11.2012

RP Rate versus RP Distance

Beam 1
(Sector 5-6)



Roman Pot rate

15.11.2012

RP Rate versus RP Distance

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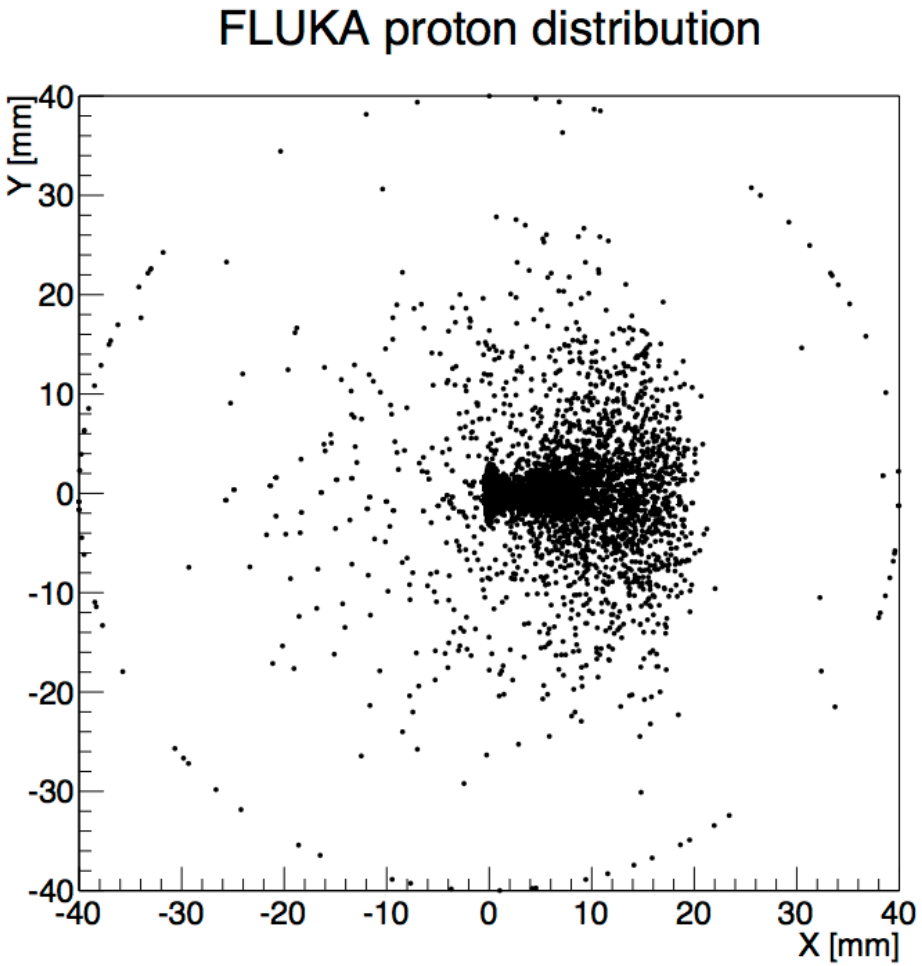
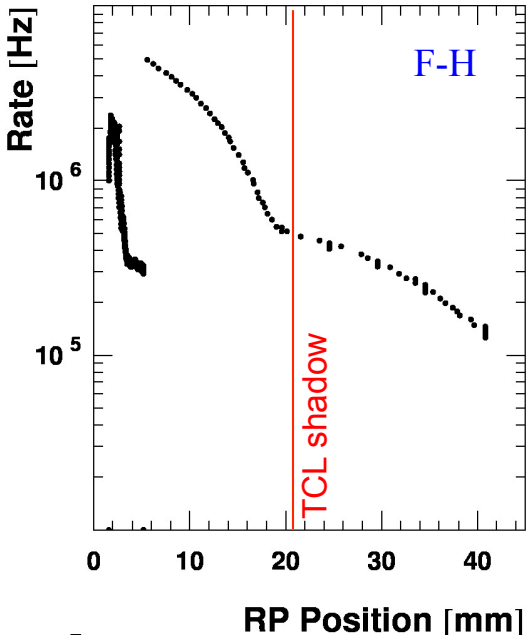
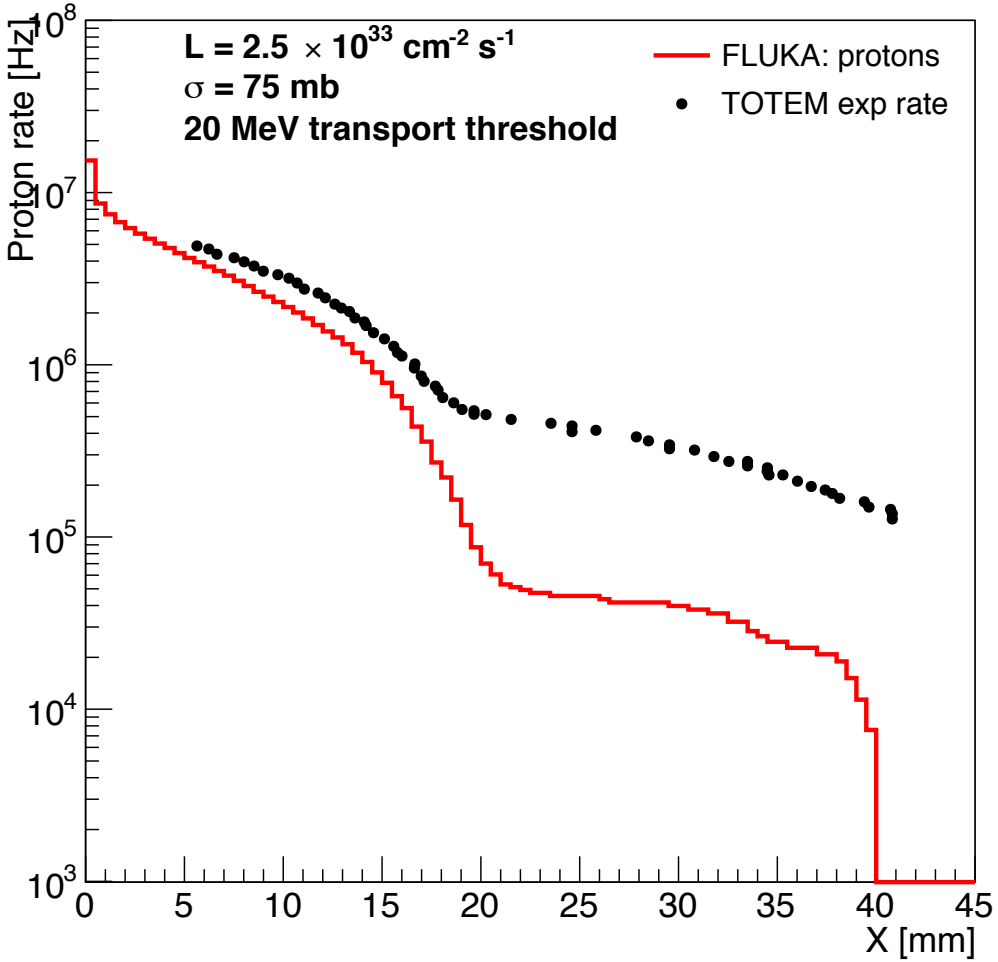
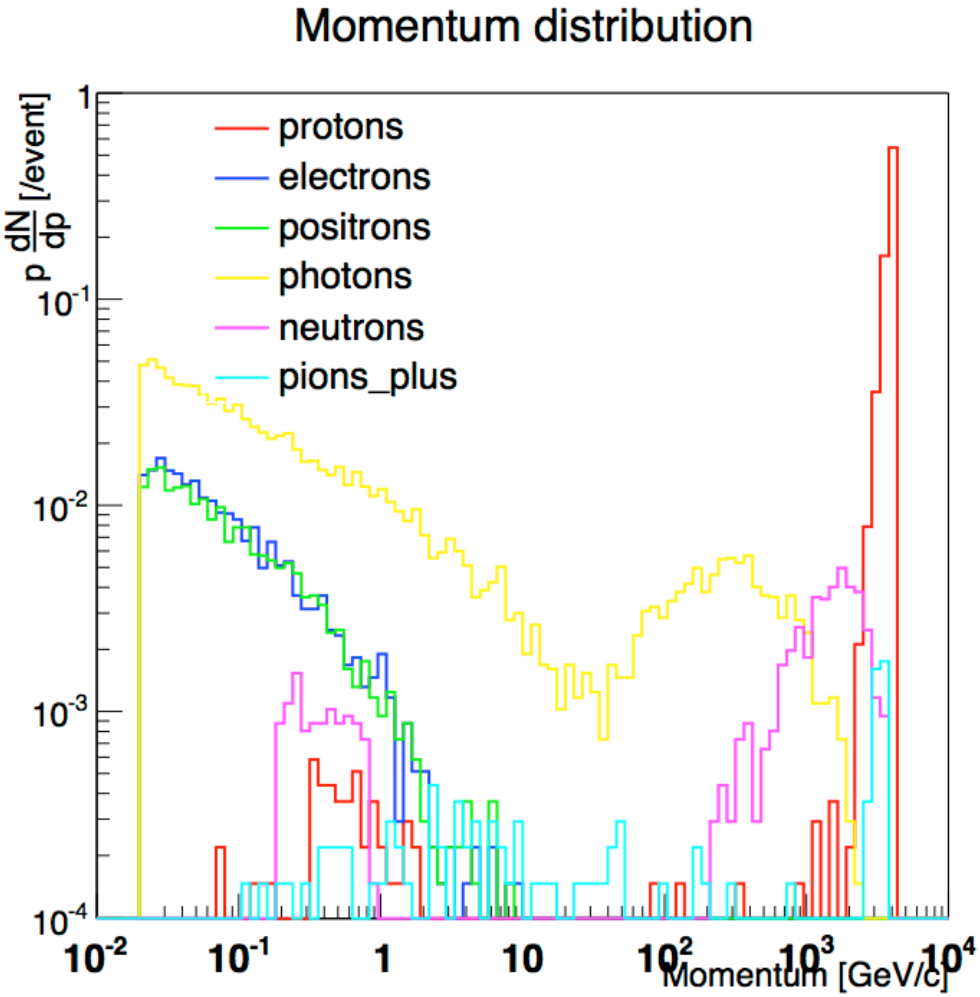
(Sector 5-6)





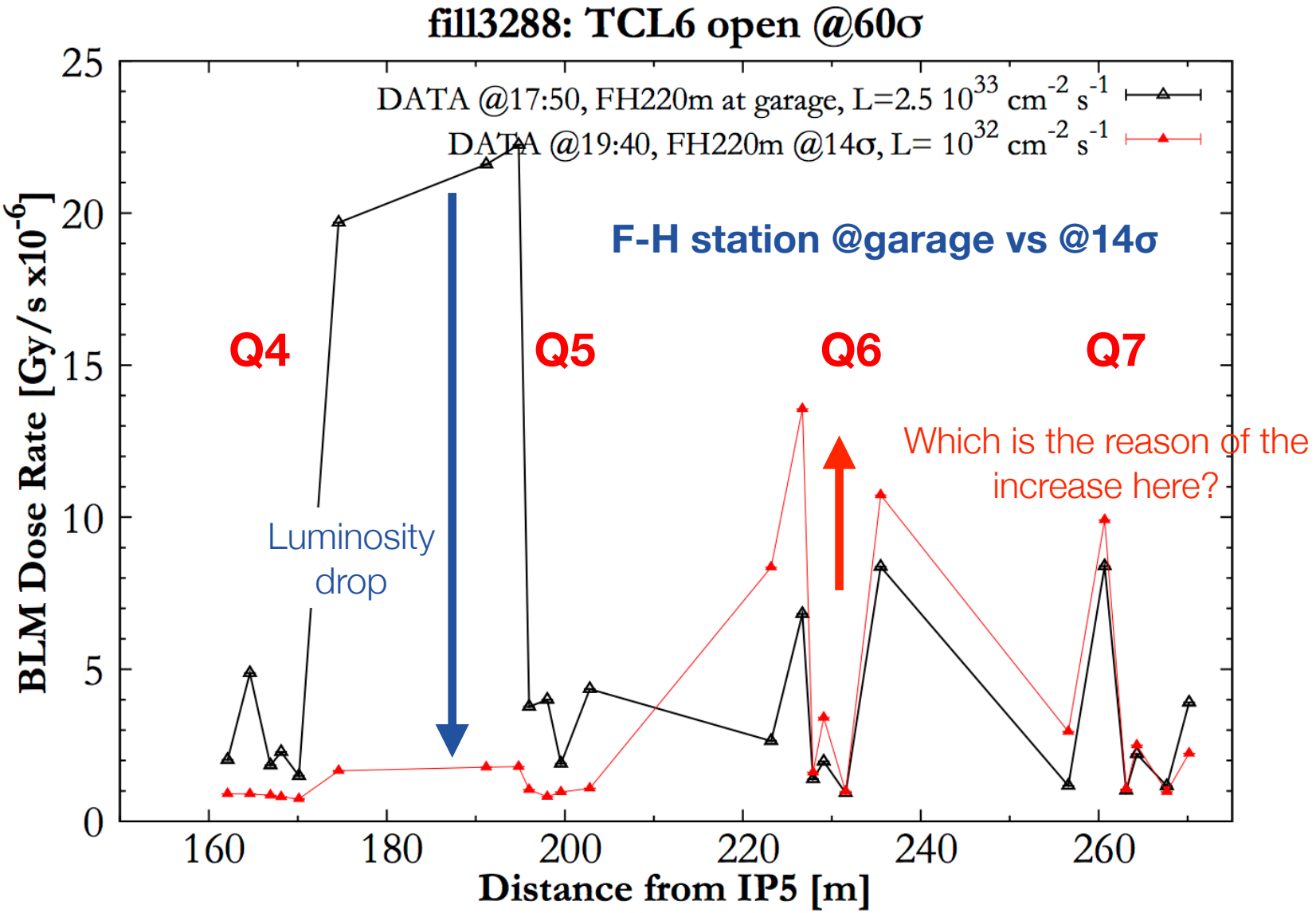
Simple FLUKA estimate of the experimental rate



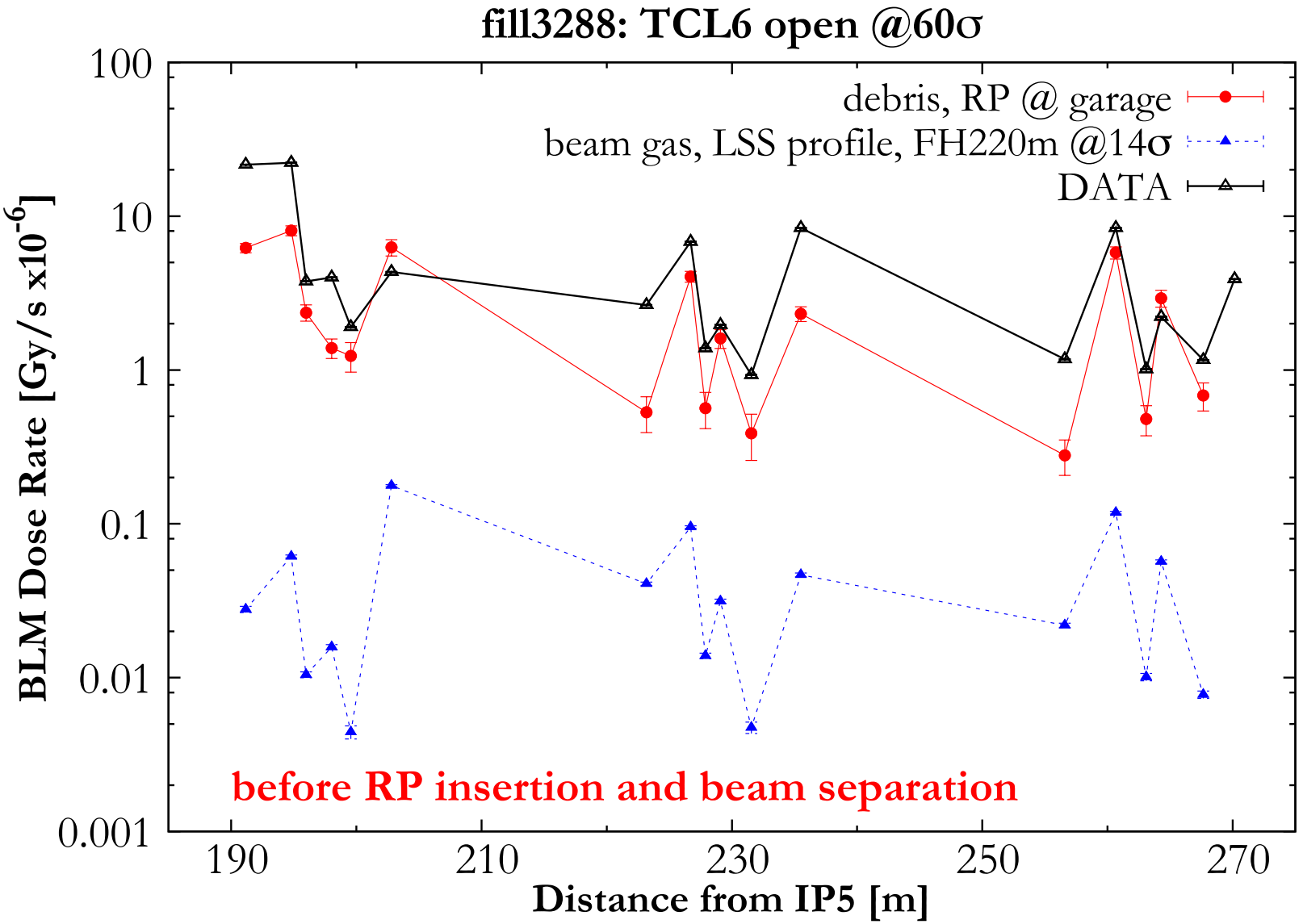


The proton rate is in a fairly nice agreement with the experimental points
A more accurate estimate would need a detailed simulation of the detector response to all the particle species

BLM response: DATA

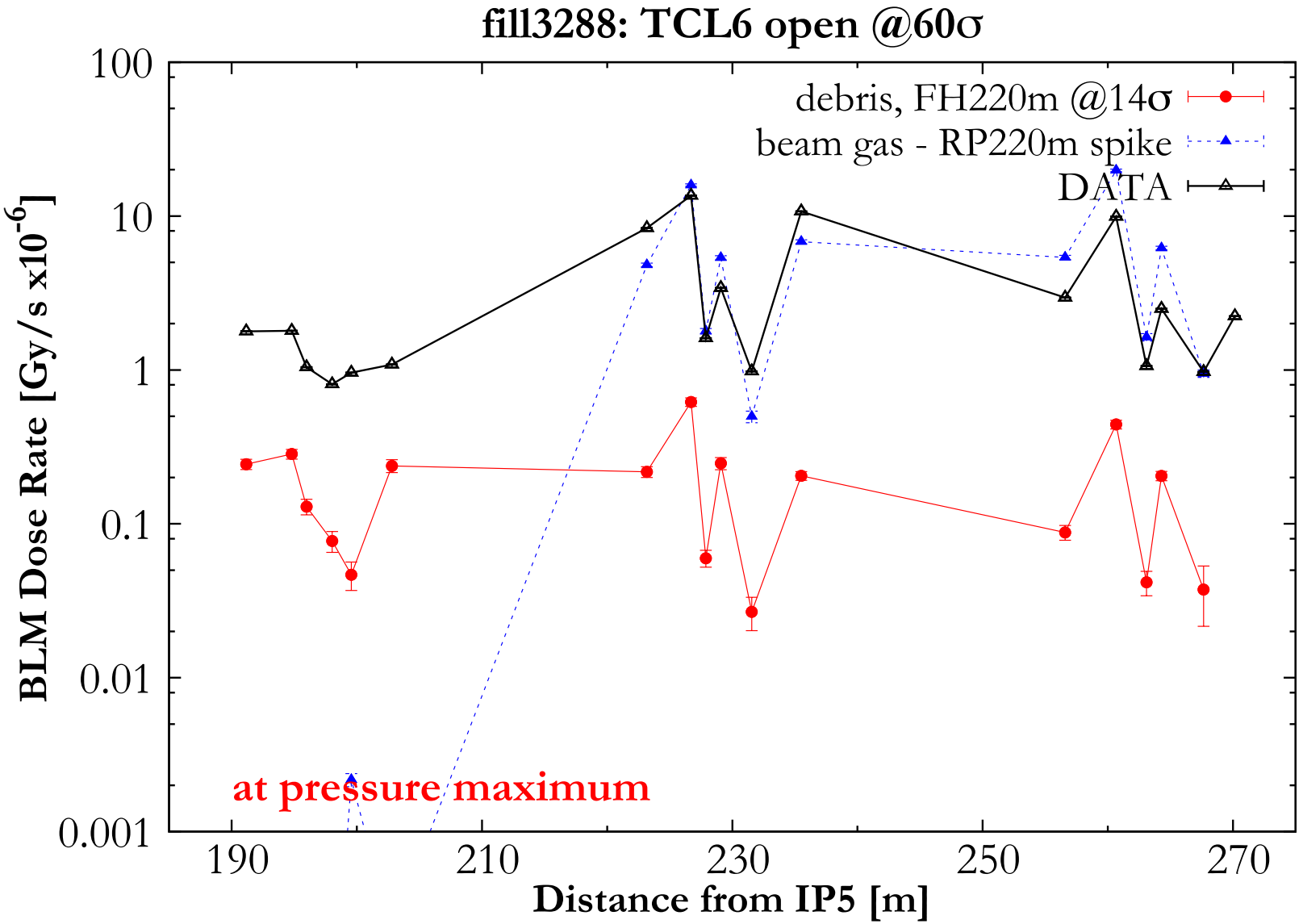


BLM response: before RP220m was operated



A "correct" contribution from beam-gas interaction should be added to collision debris

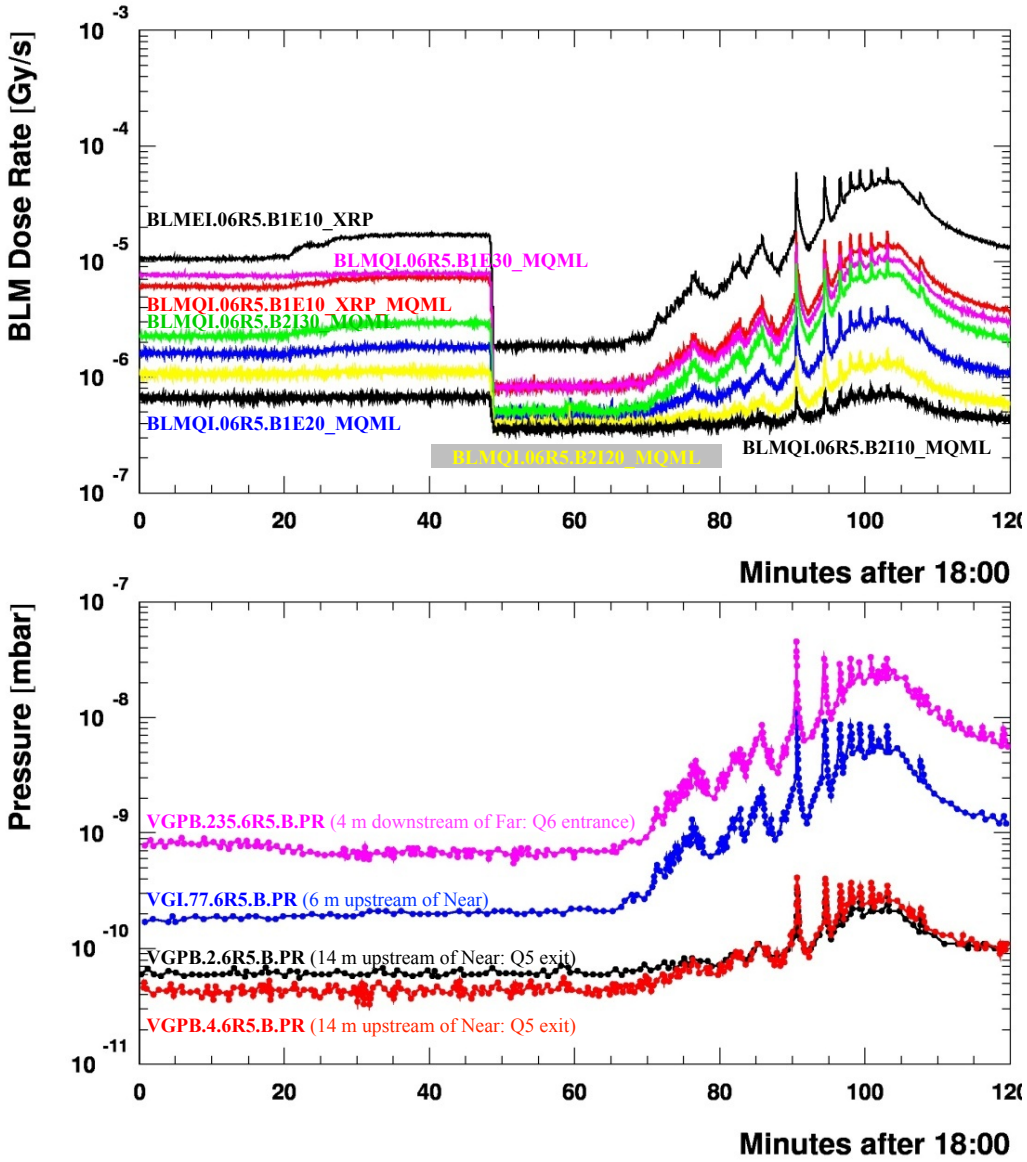
BLM response: RP220m close @14σ



Constant gas profile equivalent to 8×10^{16} H_2 molecules/m^3 over 5 m and centred around the RP position can well reproduce the BLM pattern

Comparison BLMs & Beam Vacuum

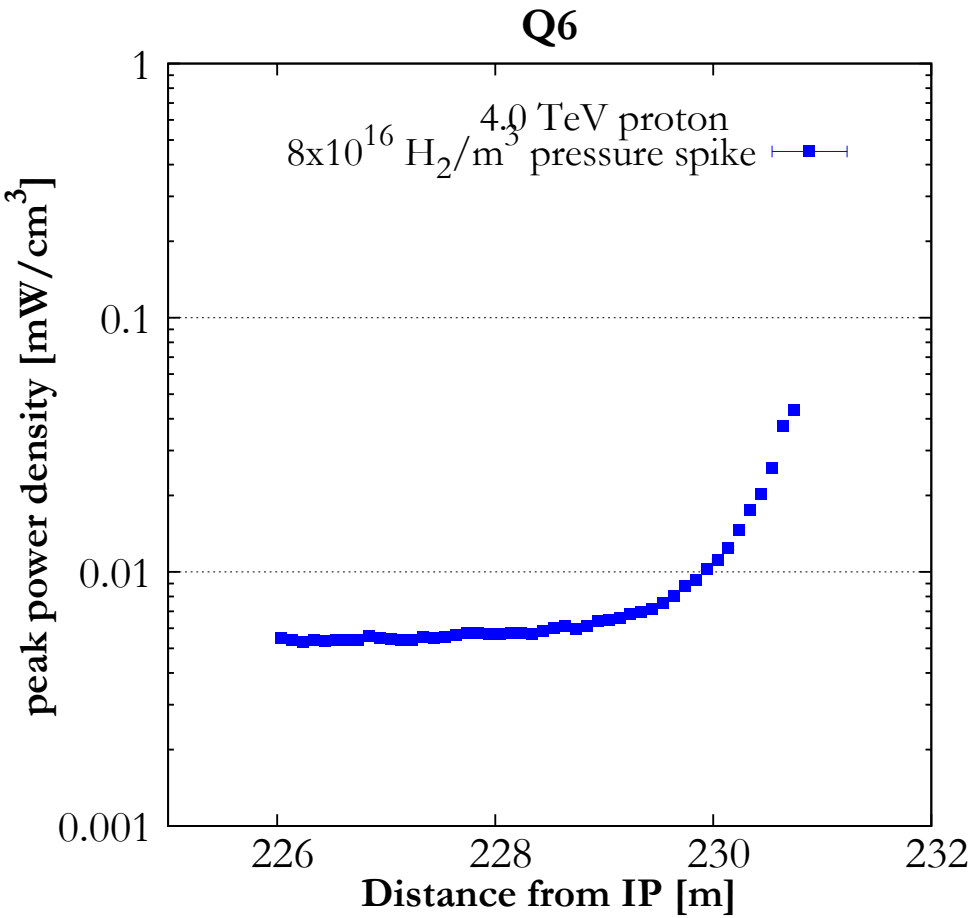
Sector 5-6

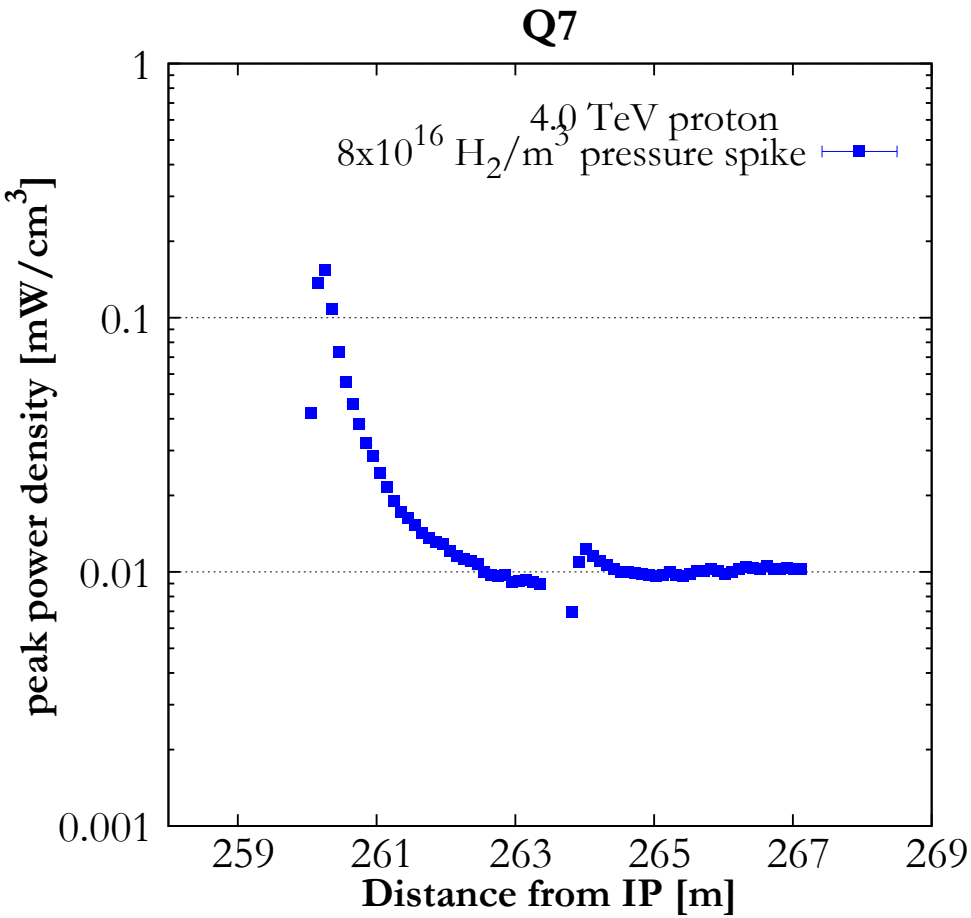


From this pressure data, one can conclude that there might be an important vacuum gradient around RP station

A spike of ~ 10^{17} H_2 molecules/m^3 would then correspond to few 10^{-6} mbar

Peak power profile in Q6-Q7 from RP-induced pressure spike





- normalisation is $I \times \rho \times \sigma_{p\text{-}H2} \times L$ where
  - $I = 0.270$ A/e
  - $\rho = 8 \times 10^{16}$ molecules/m^3
  - $\sigma_{p\text{-}H2} = 2 \times \sigma_{p\text{-}p} \simeq 2 \times 37.0$ mb
  - $L = 5.0$ m

  that gives ~ 5×10^6 interactions/s

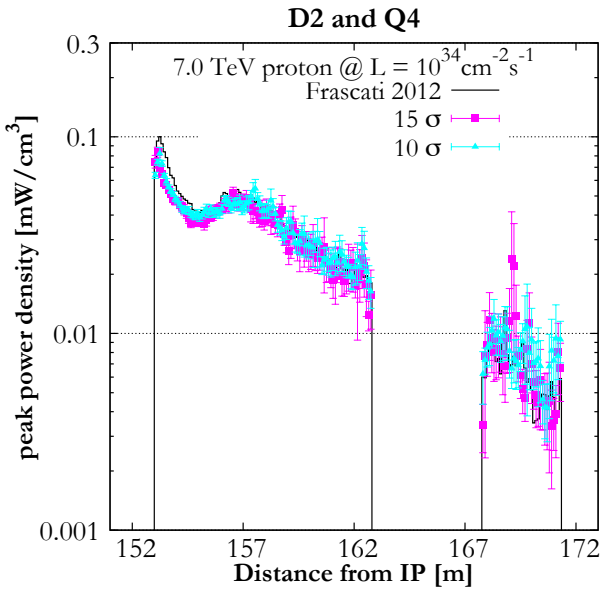
At 7 TeV a naive extrapolation can give 1 mW/cm^3 peak power density

Conclusions

- TCL6s would considerably rise the radiation level in the RR at ~ 10^{9} high-energy hadrons (>20 MeV) / cm^{2} / 100 fb^{-1}, that is still to tolerable for the equipment in there
- Installation of an iron maze like P7 is not justifiable in term of its effectiveness
- Evaluation for the HL-LHC era still need to be assessed with respect to radiation in the RR after Matching Section layout definition
- Very nice agreement with RadMon measurement, good agreement with TOTEM rate
- Observed BLM rises for RP insertion at 4 TeV can be explained by a local pressure spikes of about 10^{17} equivalent $H2/m^{3}$ (~10^{-6} mbar)
- Extrapolation at 7 TeV of the effect of a gas spike of that order gives 1 mW/cm^{3} peak power density in the Q7
- At 7 TeV, the TCL6 role to protect Q6-Q7 in this scenario can be investigated (nonetheless TOTEM upgrade should much improve the vacuum level)

Additional slides

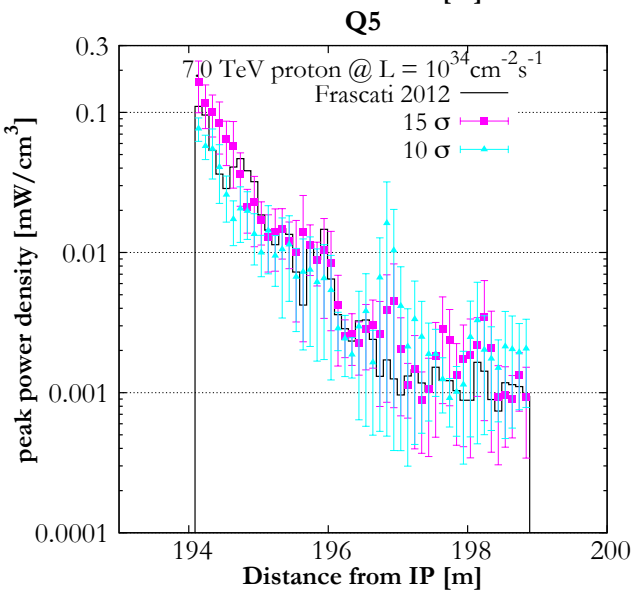
TCL@15σ

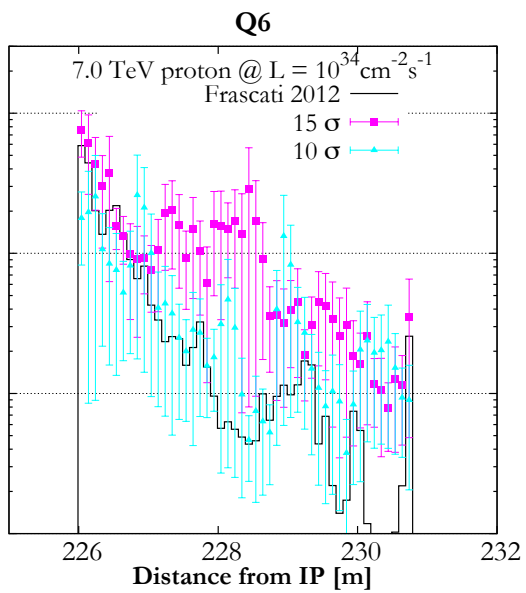


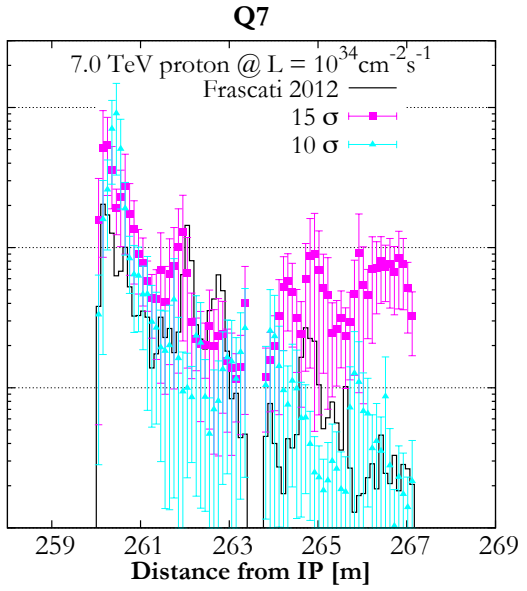
TCL4 at 15 σ provides a sufficient protection of Matching Section elements

N.B. Frascati 2012: MADX v6.500 with crossing angle at IP and orbit correctors switched off

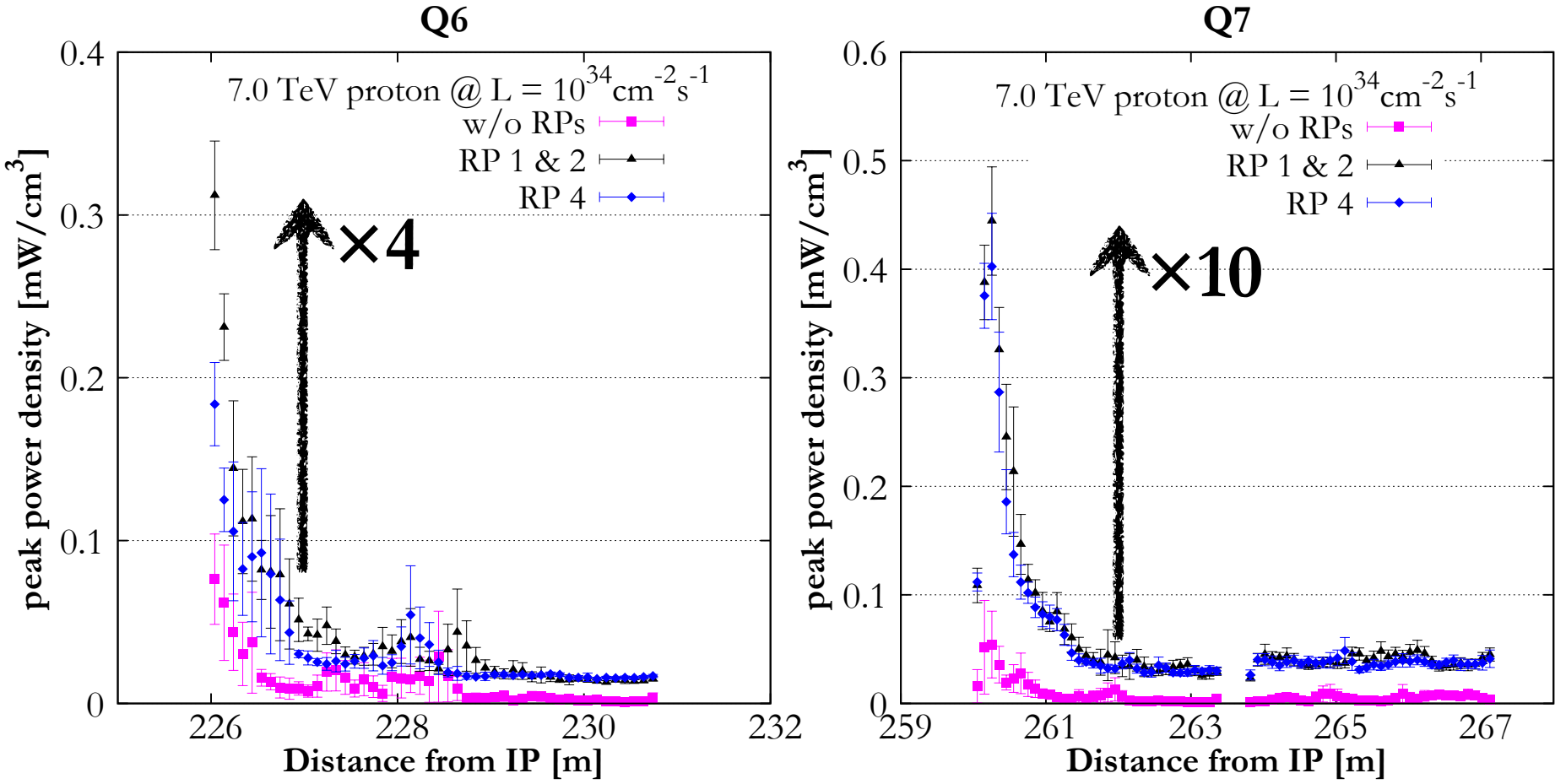
No TCL5 on the line





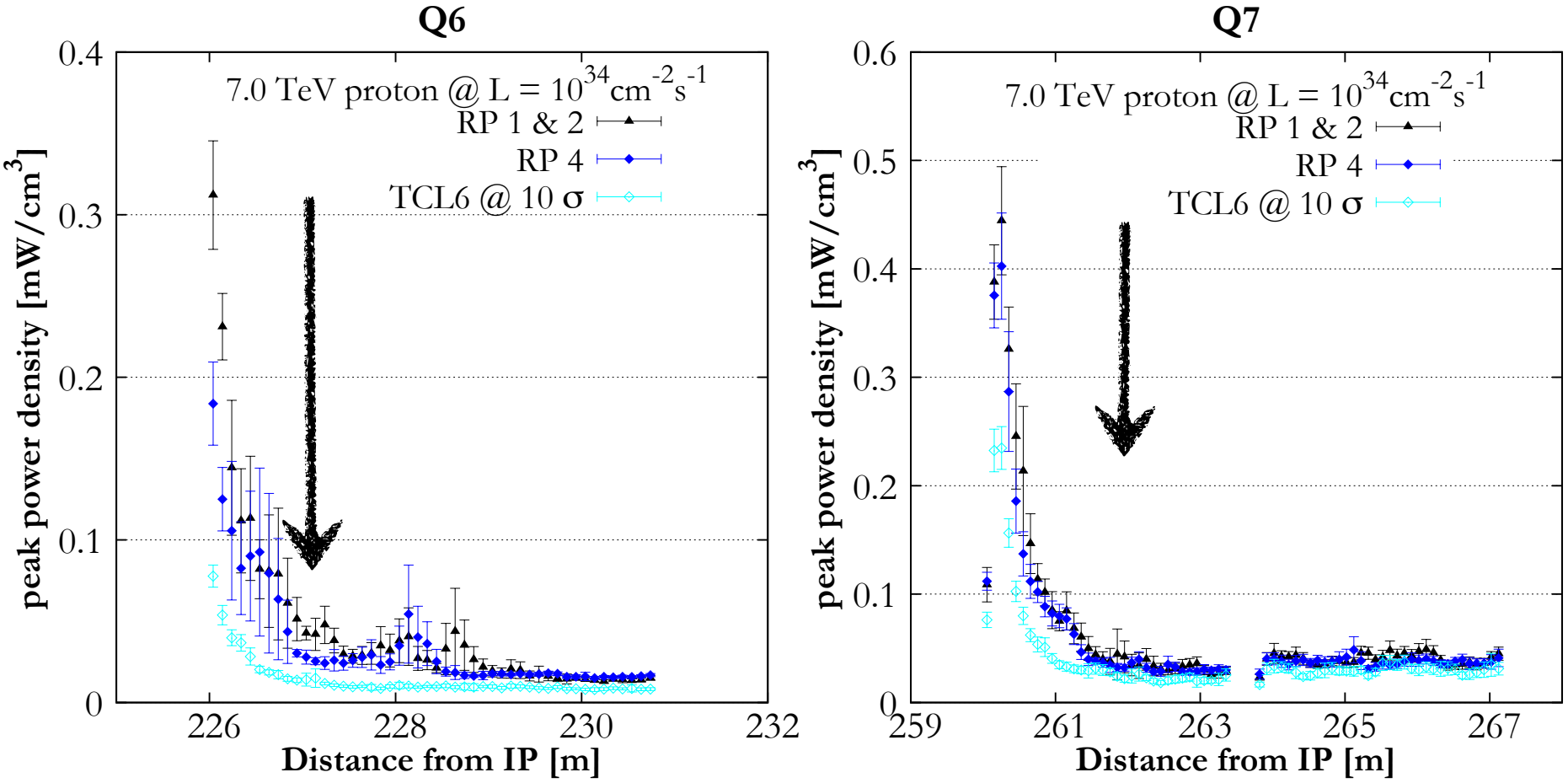


Effect of RPs



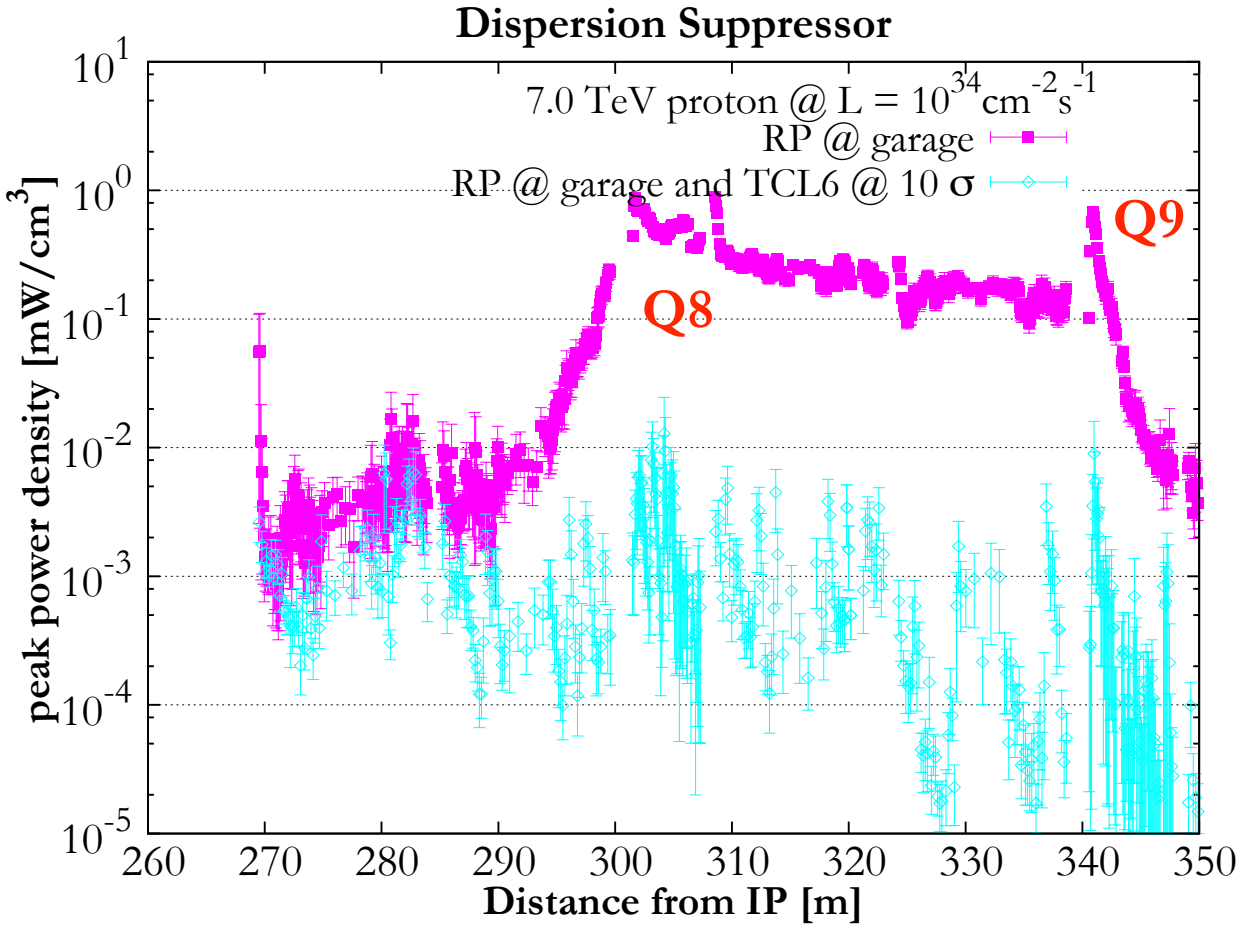
Although there is a significant increase in the peak power density on Q6 and Q7, figures are below 1 mW/cm³

TCL6 protection of MS



TCL6 reduced the peaks by about a factor 2÷3

DS protection by TCL6



- MB rebinned due to the lack of statistics
- TCL6 adsorbs about 20 W at nominal luminosity