CT-PPS Roman Pot Insertion Tests at High Luminosity

LHC Working Group on Forward Physics and Diffraction
27th October 2015

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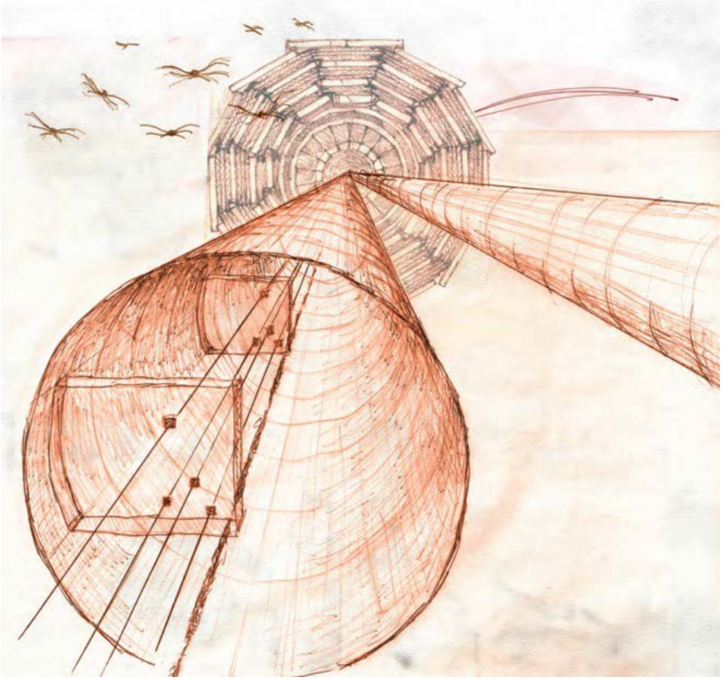
(CERN)

on behalf of
The CT-PPS Project

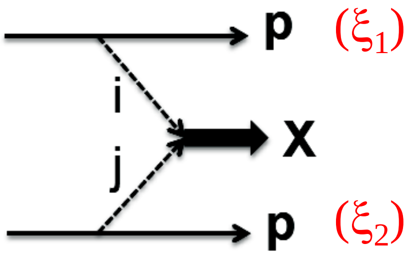


The IP5 Roman Pot System after LS1

26 Roman Pots around IP5 !

Introduction: RP Projects at IP5

Process in Focus: Central Production:

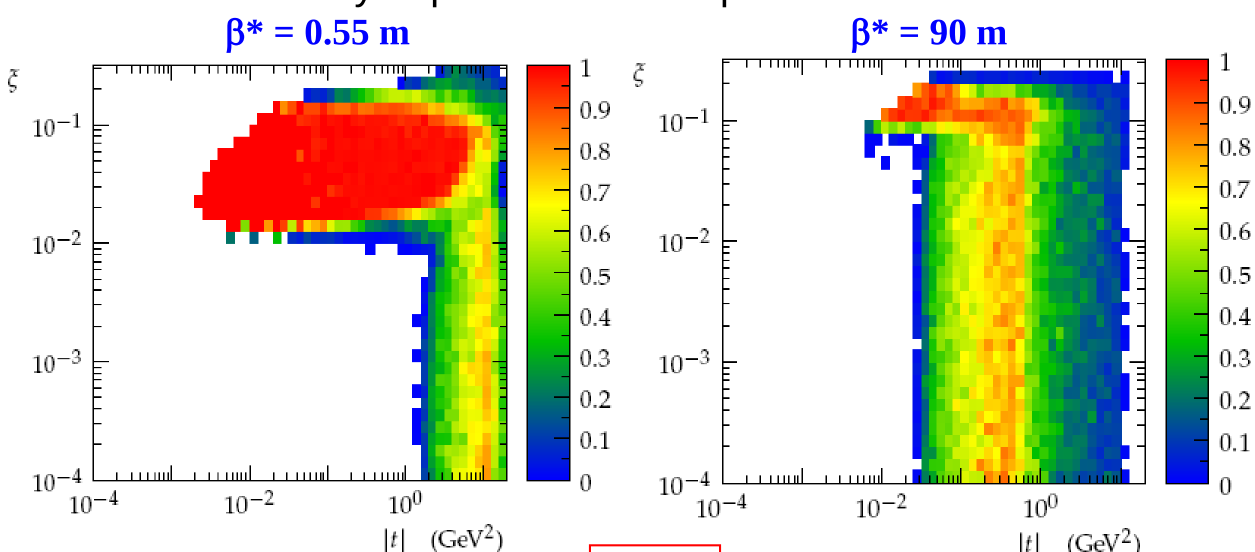


X = high E_T jets, Z, WW, ZZ, … measured in central CMS detectors

kinematic redundancy proton system – central system, e.g. $M_X^2 = \xi_1 \xi_2 s$

i, j = photon, Pomeron / Odderon (gluonic) exchanges

- Tagging with double-arm proton detection
- Operation at pileup levels μ > ~0.15 : correlation proton vertex – central event vertex via proton time-of-flight difference
- Acceptance and luminosity depend on beam optics:

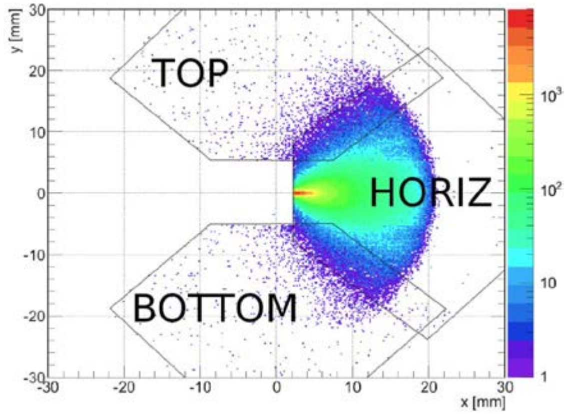


$$\mathcal{L} \propto \frac{1}{\beta^*}$$

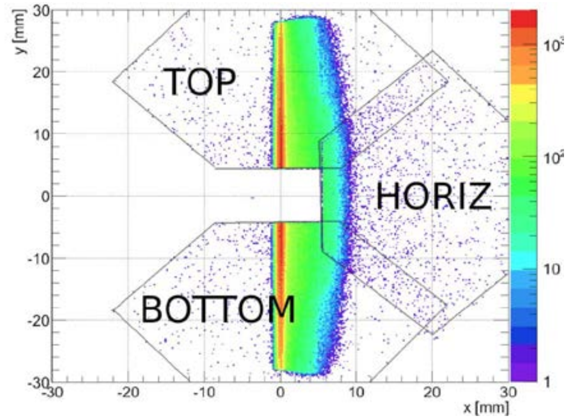
Introduction: RP Projects at IP5

Hit maps of simulated diffractive events for 2 optics configurations

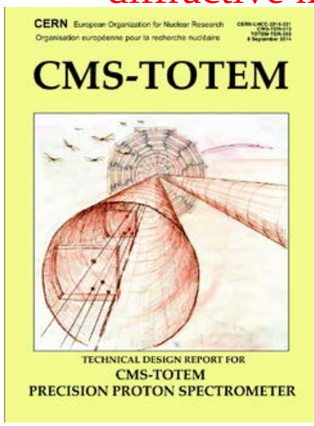
β^* = 0.55 m (low β^* = standard at LHC)



β^* = 90 m (special development for RP runs)



Operation at low β^* (< 1 m),
high luminosity (O(fb^{-1}/day)), standard runs
diffractive masses > ~300 GeV



[CERN-LHCC-2014-021]

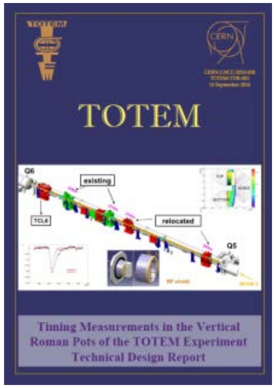
CMS-TOTEM Precision Proton Spectrometer (CT-PPS):

Tracking and Timing detectors in horizontal Roman Pots

→ general CT-PPS talk by M. Gallinaro in this workshop

Complementary project (not covered here):

Operation at high β^* (19 m, 90 m, > 1 km),
Low - medium lumi. (< 6 pb^{-1}/day), special runs
all diffractive masses



Timing Measurements in the Vertical Roman Pots of the TOTEM Experiment

Tracking and thin diamond timing detectors in vertical Roman Pots

RP Insertions in Regular Fills at Low β*

Objective of low-β* RP operations in 2015:

Establish Roman Pot insertions for physics operation in all regular fills from 2016 on

Problems during first Insertion Tests in 2012:

No beam instabilities observed

But impedance heating combined with outgassing:

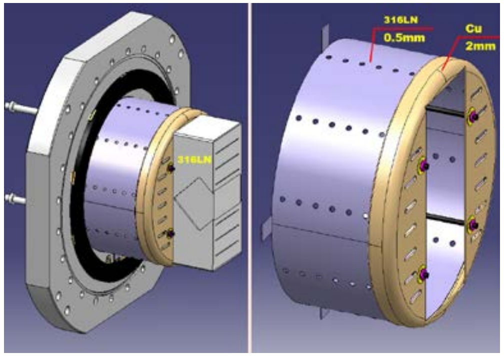
- measured temperature rise on electronics cards inside RPs despite active cooling
- traces (black spots) of metal overheating on bellow next to a ferrite fragment
- ferrite (Ferroxcube 4S60, not baked out at 1000 ºC) outgassing
  → vacuum deterioration
  → amplification of collision debris showers → dumps on BLMs

RP Insertions in Regular Fills at Low β*

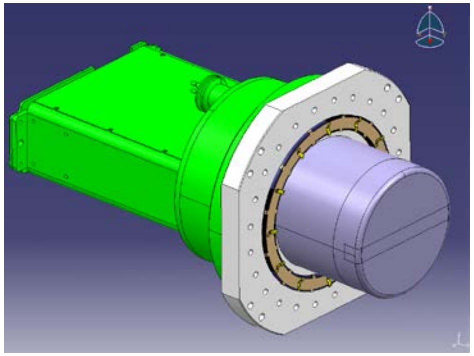
Technical Improvements during LS1

[see e.g. LHC-XRP-EC-0010, LHC-XRP-EC-0011]

- New ferrite material for all RPs (Transtech TT2-111R) like for collimators
  → higher Curie temperature
- Ferrite bake-out at 1000 °C
  → less outgassing
- Installation of RF shields in horizontal RPs for high-lumi operation,
  new ferrite geometry
  → significant impedance reduction



- Cylindrical RP geometry for new timing RPs
  → significant impedance reduction
  → but more material along the beam
  (12 cm for cylindrical pot instead of 5 cm for old box-shaped pot)



- TCL6 to intercept showers from RPs

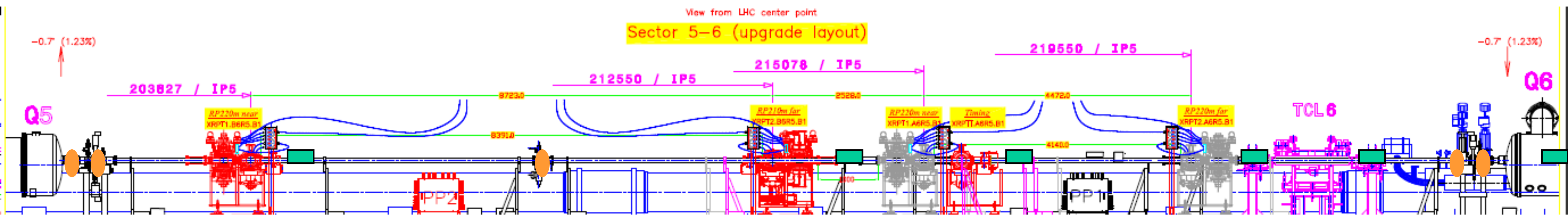
→ 2015: test effectiveness of modifications by inserting RPs in all steps of intensity ramp-up

RP Insertions in Regular Fills at Low β*

Commissioning Programme Philosophy:

- Study beam losses / showers and interplay with TCL collimator system
  extended BLM system: 1 monitor after **almost each RP unit**,
  after TCL6 and at the quadrupole Q6

- Study RP impact on impedance:
  - heating: temperature sensors on/in RPs
  - vacuum: 5 gauges in RP sector: DCS monitoring
  - beam orbit stability: monitored by impedance group



XRP.C6R5

XRP.D6R5
8° rotated unit

XRP.A6R5

XRP.E6R5
cylindrical pot

XRP.B6R5

Beam Loss Monitor (BLM)

Vacuum Gauge

Operation at low β*

Operation at high β*

RP Insertions in Regular Fills at Low β*

3 – 4 July: Beam-based alignment of all 14 low-beta RPs in 1½ hours,

5 – 14 July: RP insertions in all intensity steps of 50 ns intensity ramp-up

still nominal TCL configuration: TCL5 in, TCL6 out,

very conservative RP positions due to orbit uncertainties: **~ 30 σ horizontally, ~ 20.5 σ vertically**

3, 50, 152, 296, 476 bunches per beam → **lumi up to 1.3 x 10^{33} cm^{-2} s^{-1}**

13 – 21 August: RP insertions in first part of 25 ns intensity ramp-up

final TCL configuration: TCL5 out, TCL6 @ 25 σ

closer RP positions: **~ 25 σ horizontally, ~ 19.5 σ vertically**

2, 86, 157, 219, 315 bunches per beam → **lumi up to 0.7 x 10^{33} cm^{-2} s^{-1}**

Technical Stop 2: Installation of Aluminium bar in cylindrical pot in 5-6 mimicking the material of a Cherenkov Quartz bar

Since 5 Sept (ongoing): RP insertions in second part of 25ns intensity ramp-up

So far: 2, 49, 219, 459, 745, 1033, 1177, 1321, 1464, 1608, 1825 bunches per beam

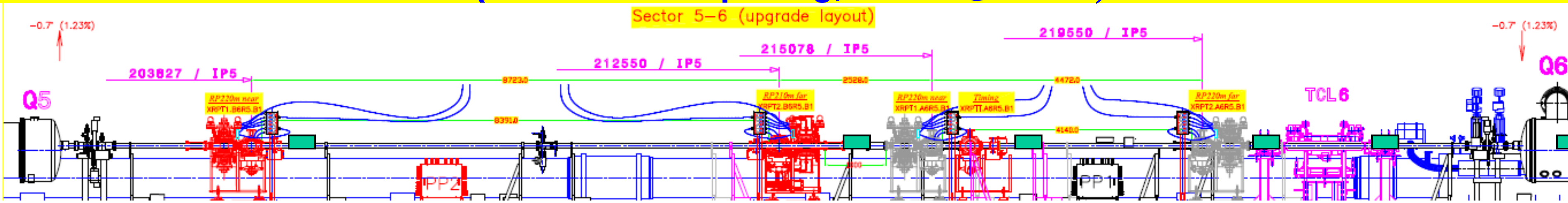
→ **lumi up to 3.9 x 10^{33} cm^{-2} s^{-1}**

So far: no beam instabilities due to RP insertions observed.

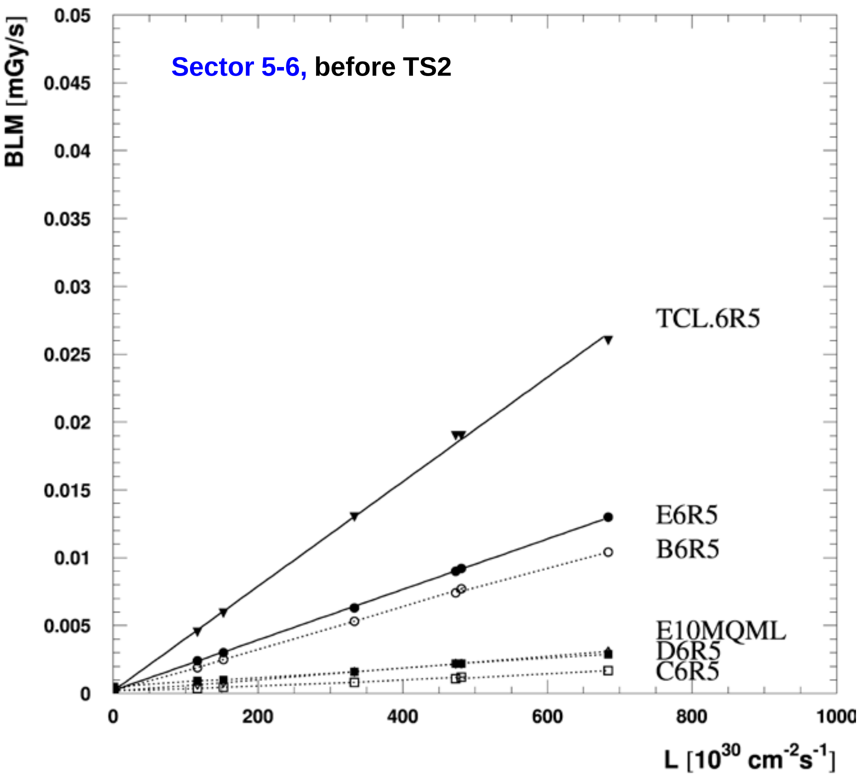
Aim for RP positions next year if all insertions successful:

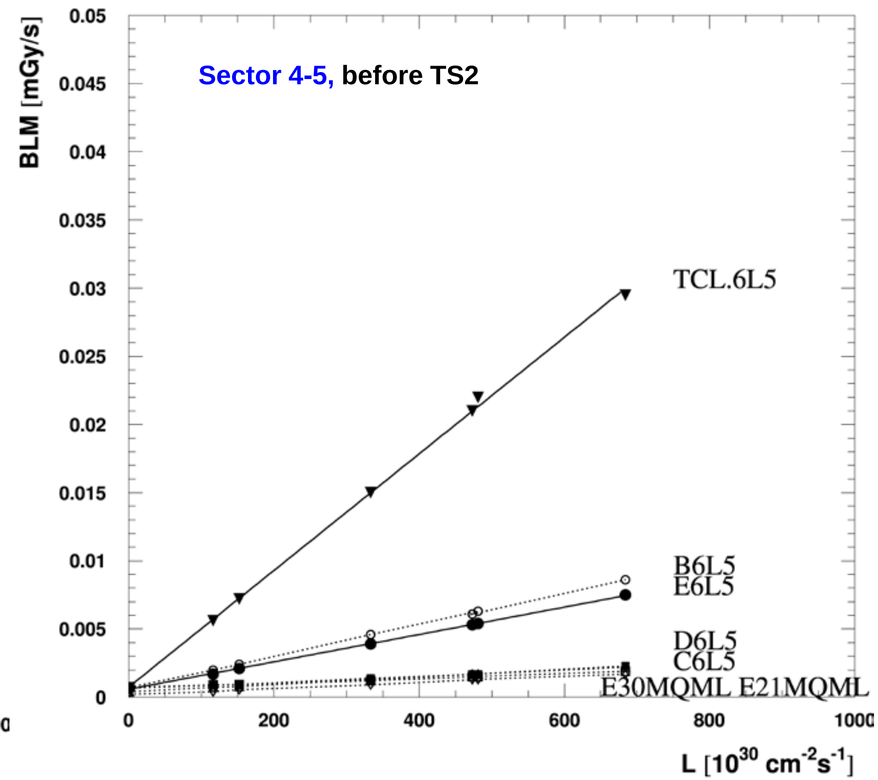
20.7 σ horizontally, 18.2 σ vertically or closer if collimation system allows

BLM Response to RP Insertions
(25 ns bunch spacing, XRPH @ ~25 σ)



BLM: C6R5 D6R5 E6R5 B6R5 TCL.6R5 E10MQML

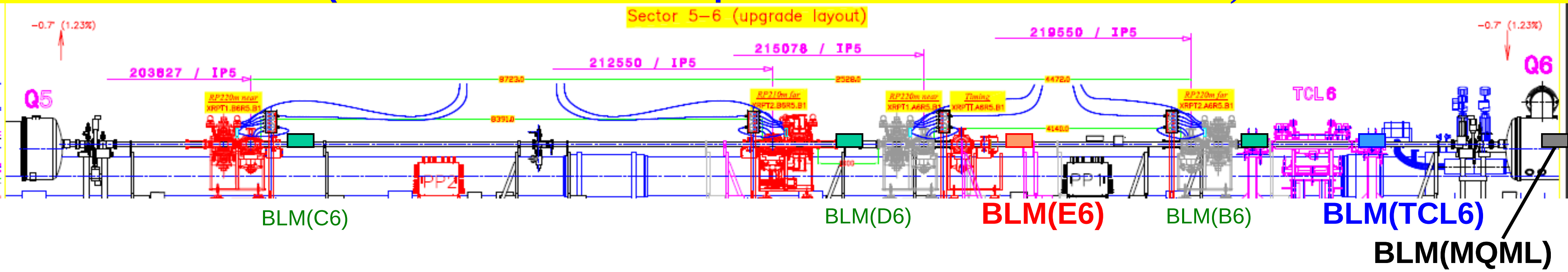


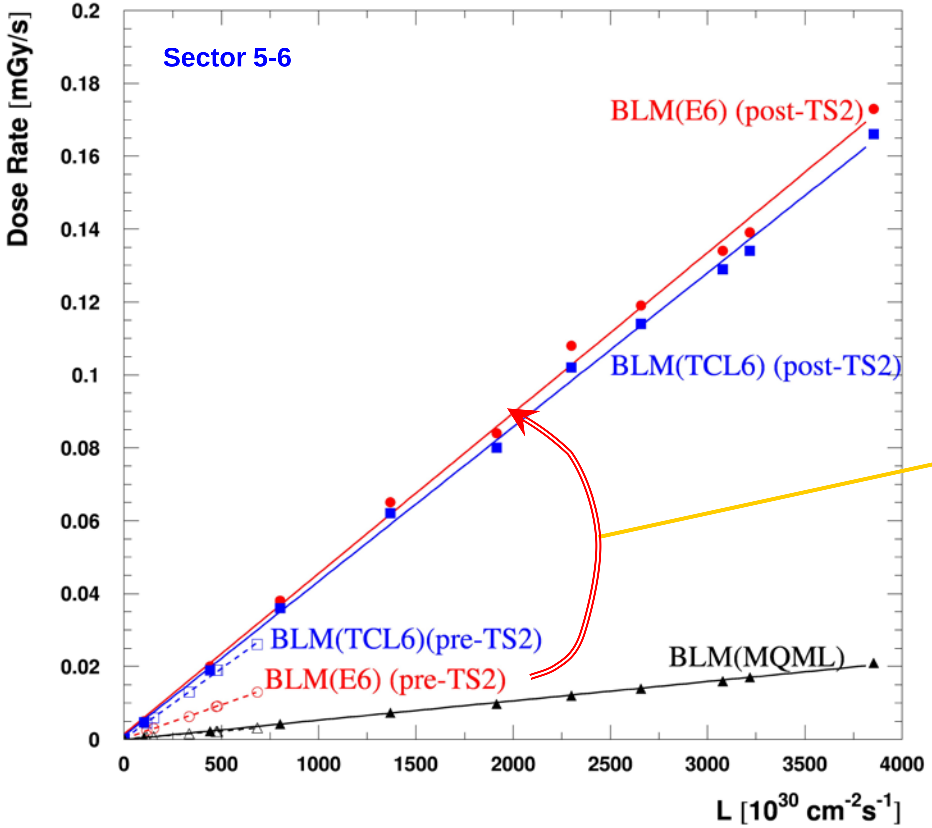


- Dose rates proportional to luminosity → showers = collision debris, not single-beam halo
- RP generating strongest shower dose rate: cylindrical pot (E6): most material
- Strong dose rate in BLM(TCL6), very small signals in quadrupose BLMs → **TCL6 is effective**

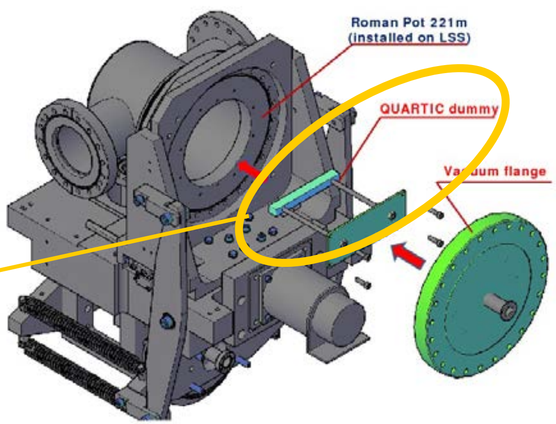
BLM Response with and without Dummy Quartic Bar in RP

(Insertion of horizontal pots to ~25 σ from beam centre)





Technical Stop TS2:
Installation of Al bar (Quartic dummy) in the pot



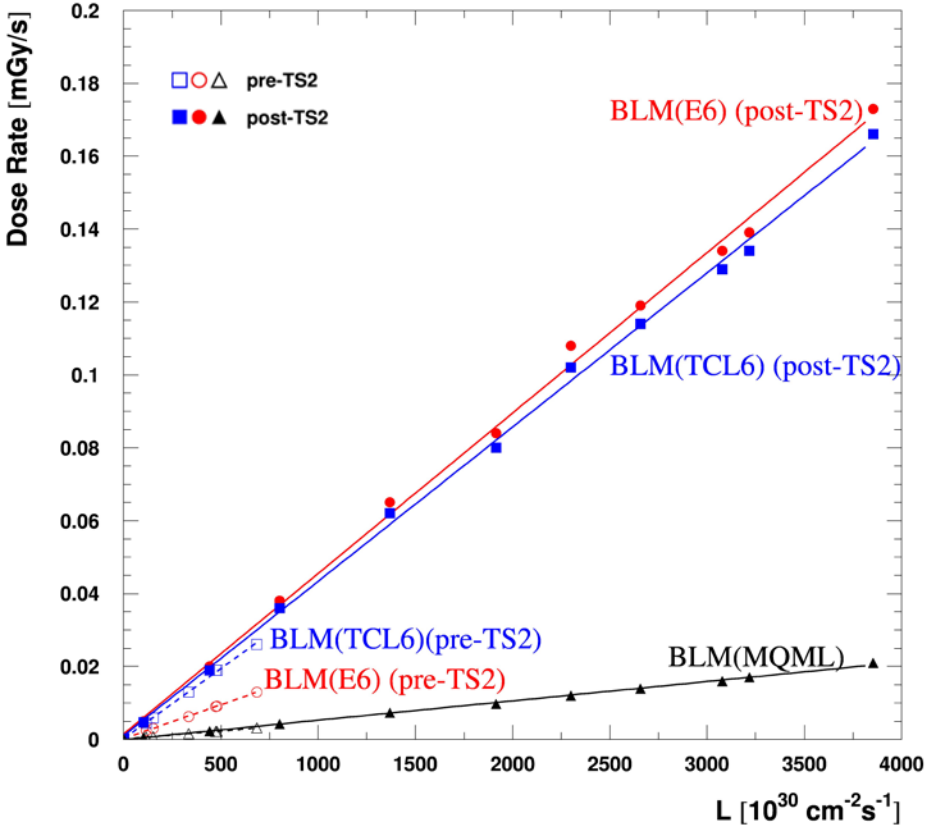
Installation of dummy QUARTIC bar → dose rate in BLM(E6) increases by ~ factor 2

BLM Response before and after Technical Stop 2

(Insertion of horizontal pots to ~25 σ from beam centre)

Sector 5-6

Aluminium bar installed in TS2

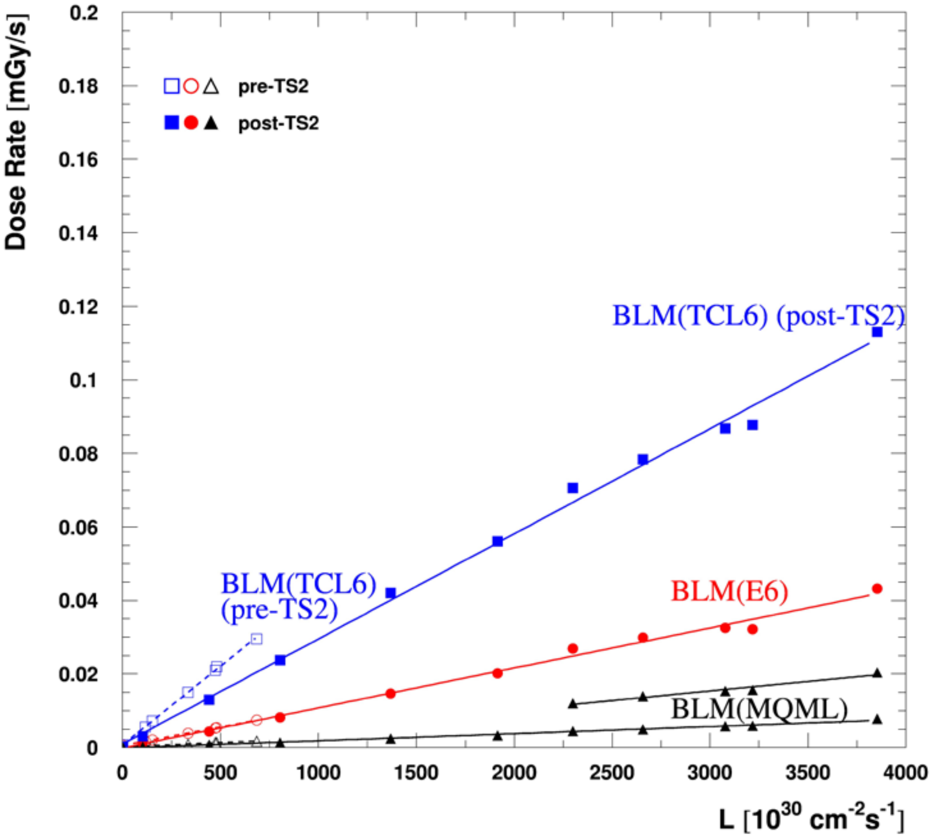


Installation of dummy QUARTIC bar
→ dose rate in BLM(E6) increases by ~ factor 2

Linear Extrapolation to L=10^{34} cm^{-2} s^{-1} :
BLM(E6) = 0.47 mGy/s = 0.07 Threshold
→ no problem from BLMs expected

Sector 4-5

no Aluminium bar installed



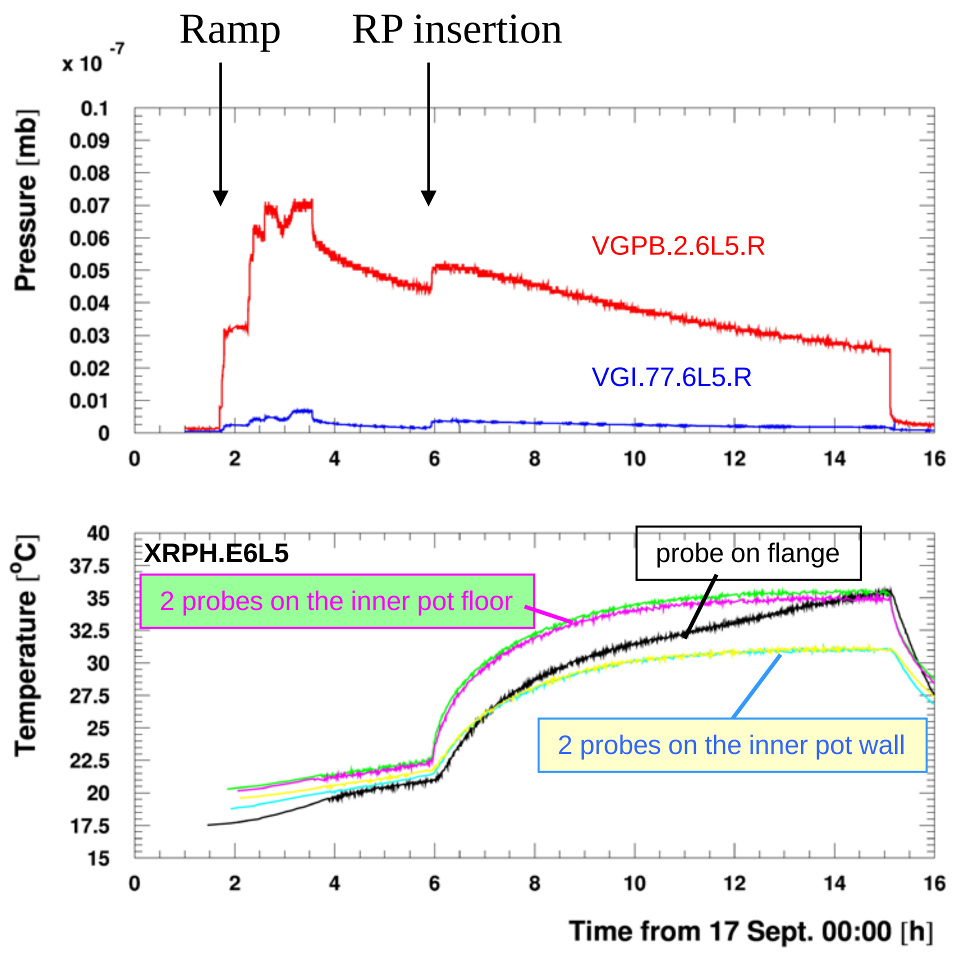
Losses before and after TS2 are compatible.

Slight change in BLM(TCL6):
TCL6 collimator was realigned in TS2
due to a tilt in the jaws.

Vacuum and Temperature Response

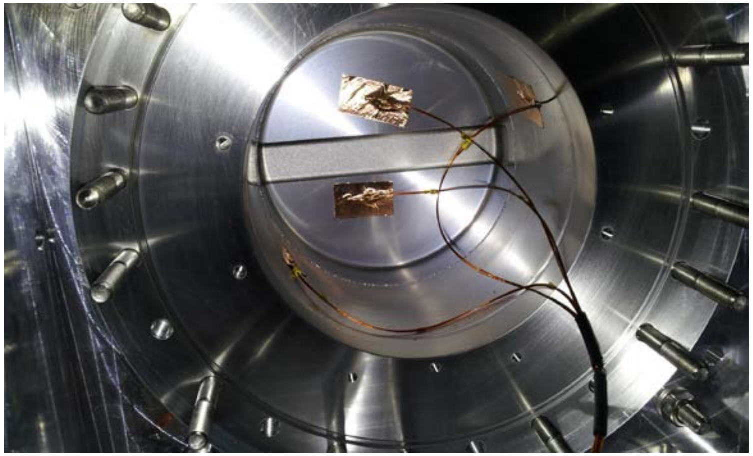
Example fill: **horizontal pots @ ~25 σ from beam centre, L ~ 1.9 x 10^{33} cm^{-2} s^{-1}**

Time evolution of pressure and temperature:



Vacuum gauges near the most upstream RP:
significant but unproblematic pressure rise

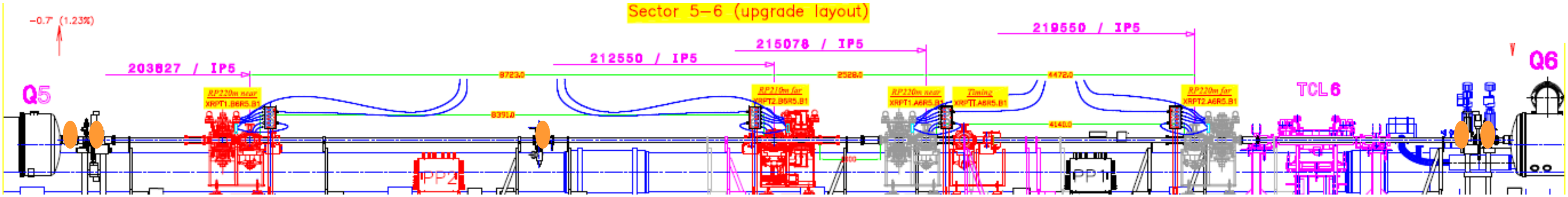
Temperature sensors on cylindrical pot:
hottest spot = pot floor (towards beam) !



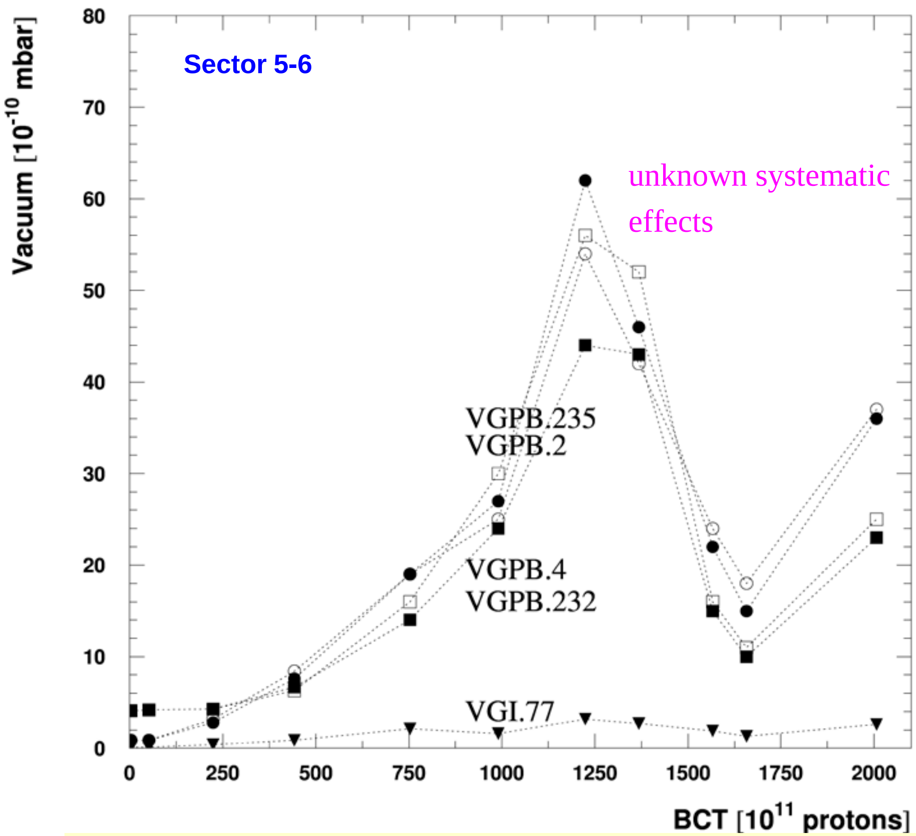
Slow temperature increase approaching an equilibrium value,
moderate magnitude: up to 36 °C at RP floor 3 mm from beam centre without cooling
Comparison: 2011 in a fill without cooling: 41 °C on RP electronics card with pot retracted (4 cm from beam)

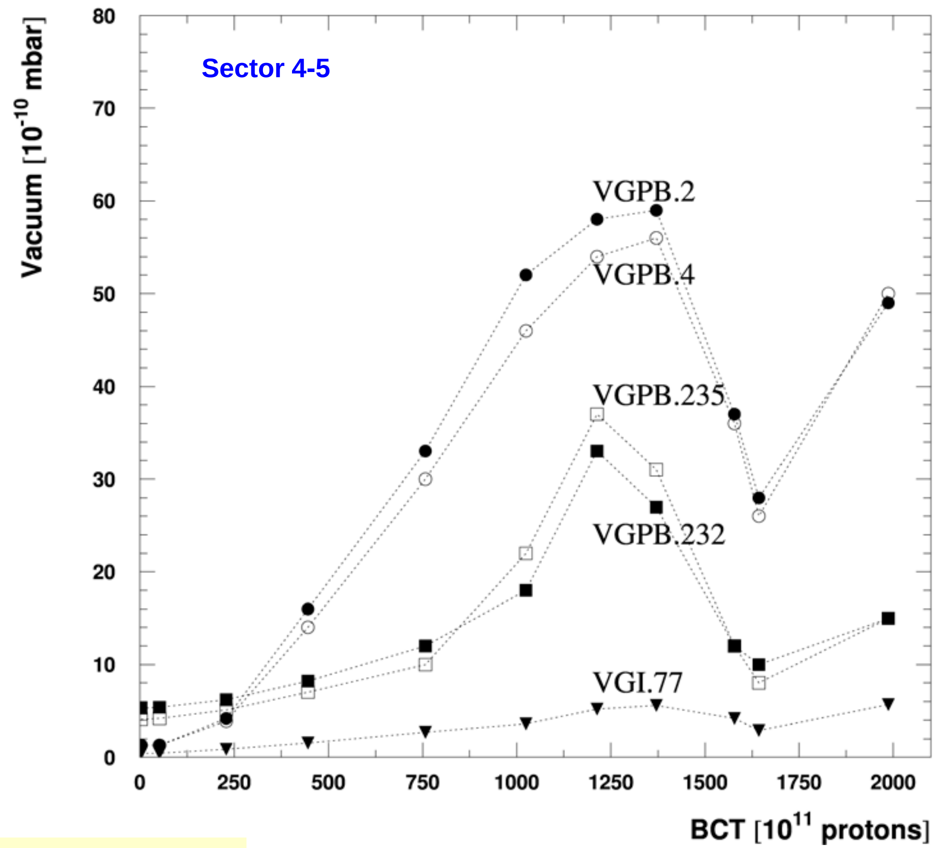
Vacuum in 25ns Intensity Ramp

Equilibrium pressure after RP insertion



VGPB.2, VGPB.4 VGI.77 VGPB.232, VGPB.235



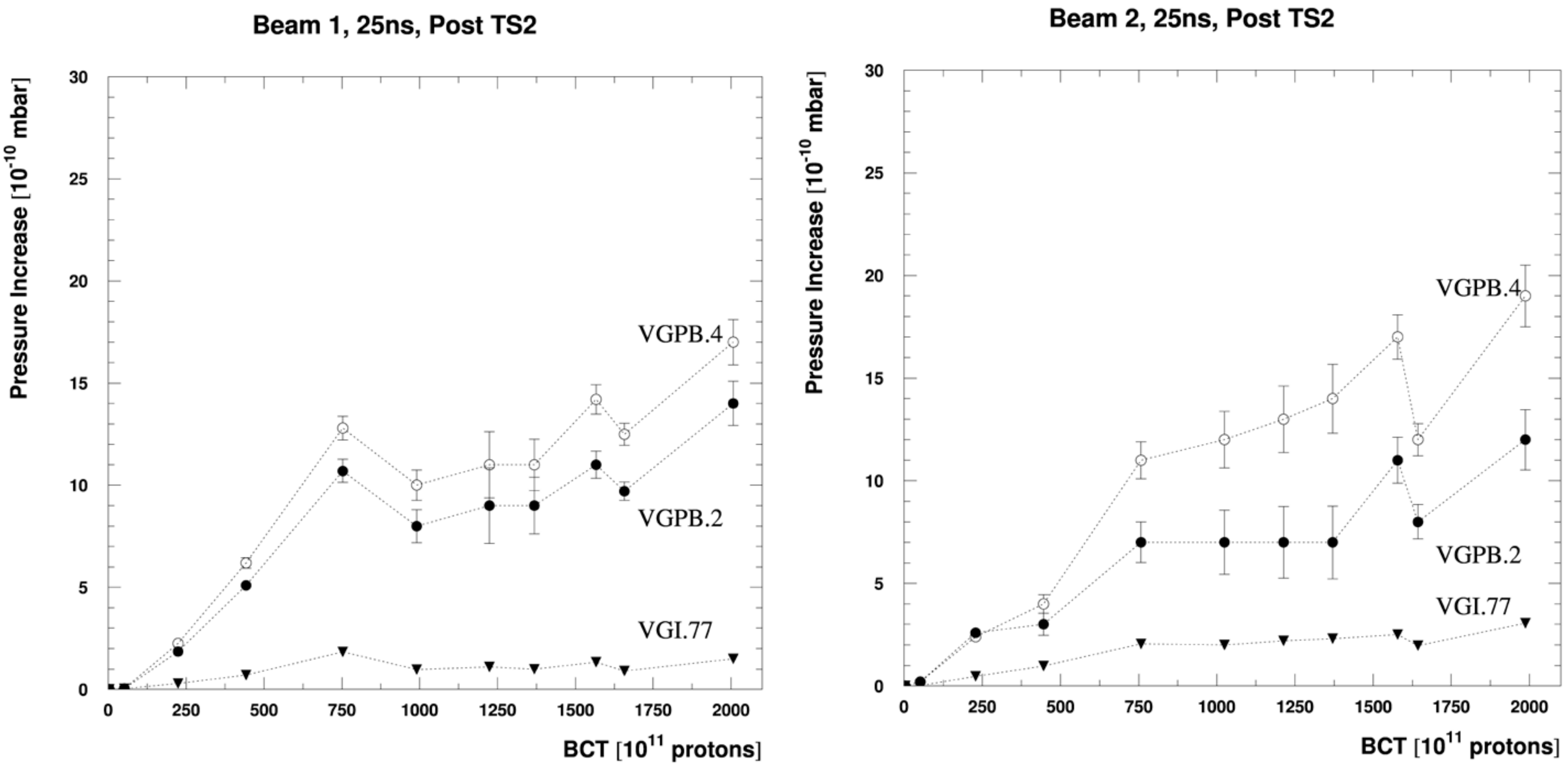


No dangerous pressure rise in machine vacuum observed.

Vacuum Pressure Rise @ RP Insertion

Most of the pressure rise with lumi is not related to RP insertion.

→ isolate RP effect by measuring only the increase at insertion time

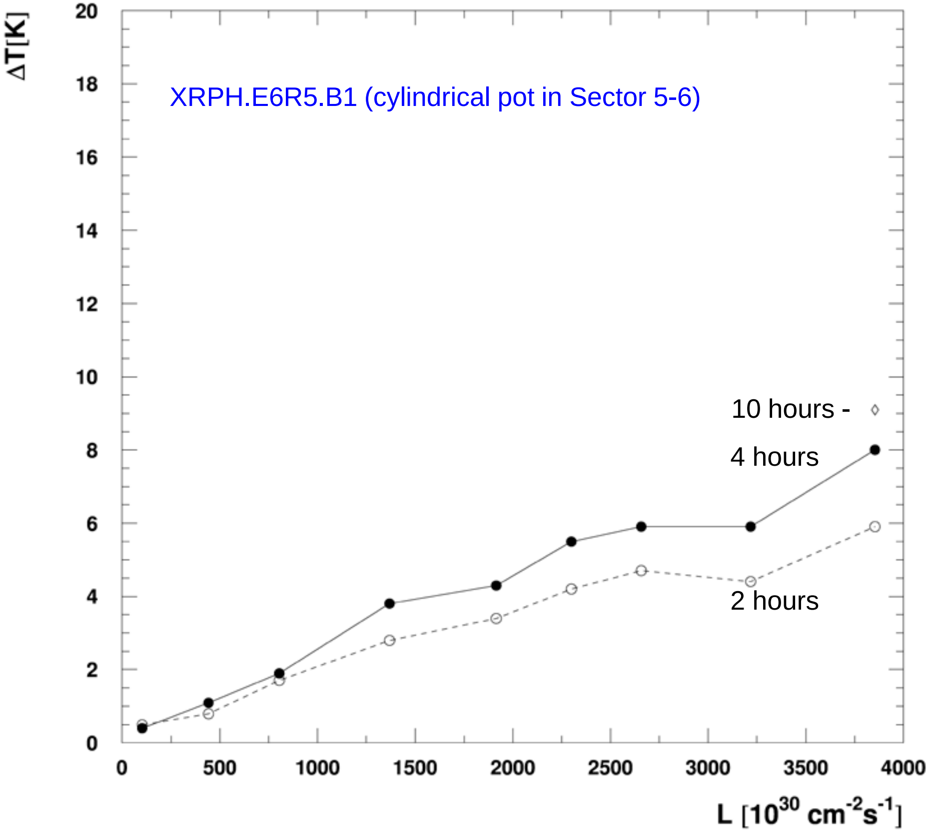


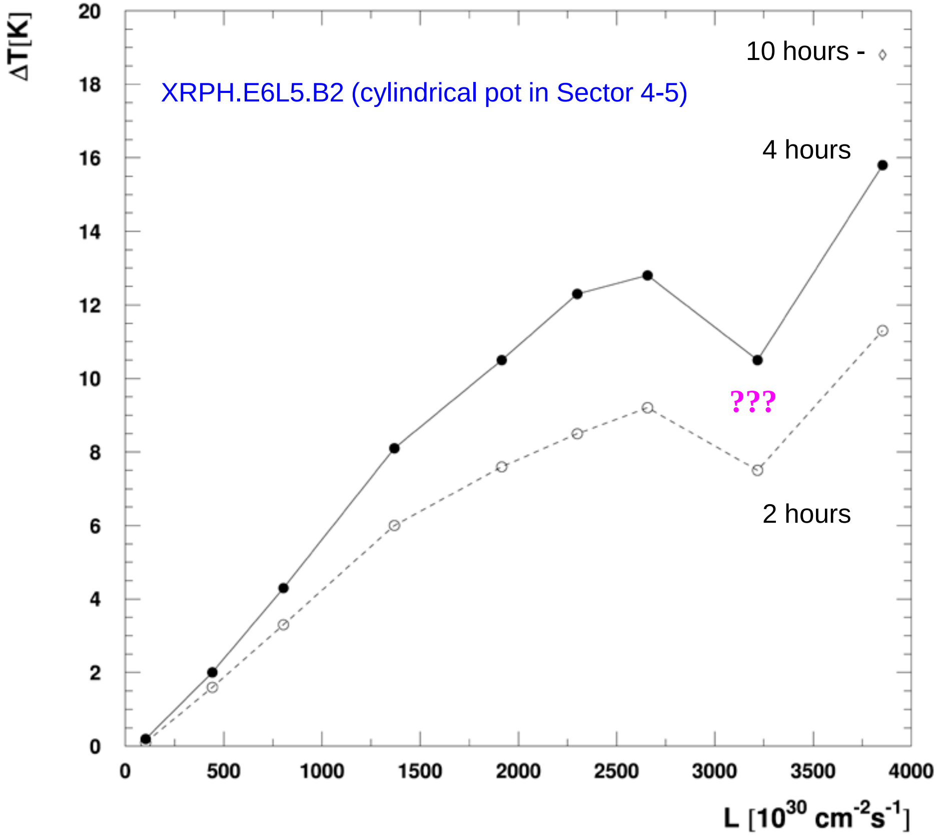
Flange Temperature Rise versus Lumi

Temperature increase on the flange of the cylindrical RPs:

no simple saturation function → no evident fit and extrapolation to the asymptotic level

→ plot the increase after 2 and 4 hours from insertion time



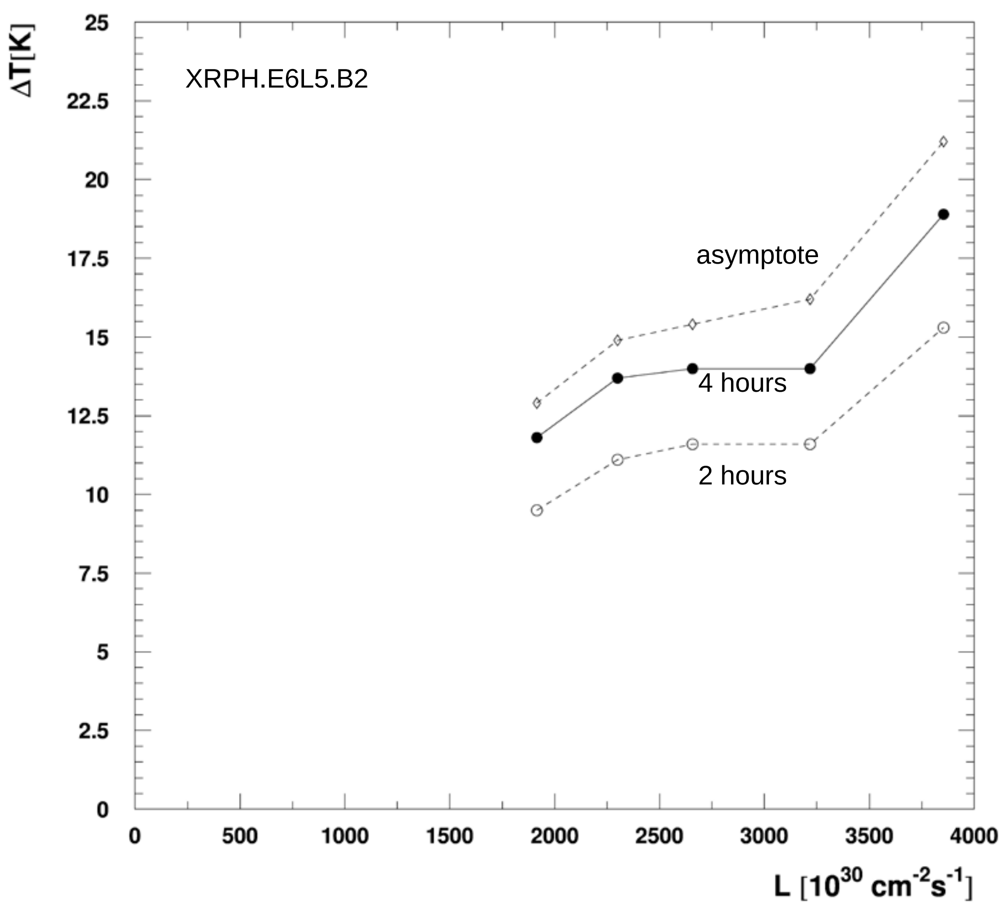


→ No problem expected, but to be watched with attention.

Sector 4-5: vortex cooling installed in cylindrical pot (presently off)

Pot Floor Temperature Rise versus Lumi

Temperature increase relative to RP insertion after 2 and 4 hours and asymptotic value
(Probe on the floor of the cylindrical RPs)



Extrapolation to $L=10^{34}$ cm^{-2} s^{-1} still unclear.

Linear estimate:
$\Delta T \approx 21\ K \times 2.5 \approx 53\ K$
→ temperature reached:
20 ºC + 53 K = 73 ºC

Conclusions from the Insertion Tests

Observations from insertions to 25 σ so far:

- BLM response: linear with luminosity,
  extrapolation to 10^{34}: no problem expected.

- Vacuum pressure: unclear dependence on luminosity, generally rising,
  other strong systematic effects,
  no problem expected, but to be watched.

- Temperature in RP: increasing with luminosity,
  no problem expected, but to be watched.
  In case of problems: cooling

- No beam instabilities introduced

If final luminosity in 2015 is reached without problems
→ next challenge: go closer ($\leq 20\ \sigma$)

RP Positions Relative to the Beam Centre and the Resulting Acceptance Limits

$\sqrt{s}$ = 13 TeV, β^* = 0.8 m, ε_n = 3.5 μm rad

		Now		Next Step (2016)	
	Horizontal RP	20.7 σ + 0.5 mm + 0.5 mm (window + gap)	ξ_{min}	20.7 σ + 0.5 mm (window + gap)	ξ_{min}
Sector 5-6 (Beam 1)	XRPH.C6R5.B1	4.416 mm	**0.052**	3.916 mm	**0.046**
	XRPH.D6R5.B1	3.422 mm	0.043	2.922 mm	0.037
	XRPH.E6R5.B1	3.111 mm	0.040	2.611 mm	0.034
Sector 4-5 (Beam 2)	XRPH.C6L5.B2	4.478 mm	**0.052**	3.978 mm	**0.046**
	XRPH.D6L5.B2	3.505 mm	0.043	3.005 mm	0.037
	XRPH.E6L5.B2	3.194 mm	0.041	2.694 mm	0.035

Minimum diffractive mass in central diffr.
(double arm measurement in C & D & E):

$M = \sqrt{\xi_1 \xi_2 s}$ M > 676 GeV M > 598 GeV

upper ξ cut by TCL4: **0.099** → M < 1.287 TeV if no other aperture limitations are present !
upper ξ cut by TCL5: 0.106

Ultimate goal: ~ 15 σ

t-Acceptance vs. Vertical RP Position

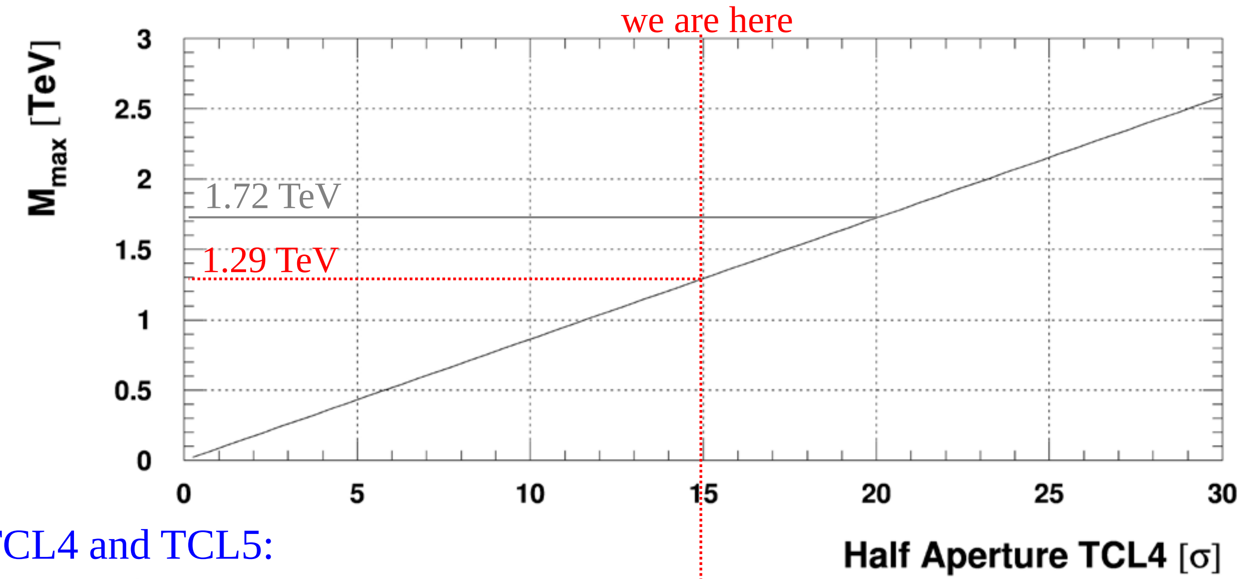
vertical at ε_n = 3.5 μm rad

	$\sigma_{y,beam}$	L_y	18.2 σ + 0.5 mm + 0.5 mm (window + gap)	$\|t_y\|_{min}$	18.2 σ + 0.5 mm (window + gap)	$\|t_y\|_{min}$
XRPV.C6R5.B1	418 μm	16.516 m	8.608 mm	11.5 GeV^2	8.108 mm	10.2 GeV^2
XRPV.D6R5.B1	386 μm	15.207 m	8.025 mm	11.8 GeV^2	7.525 mm	10.3 GeV^2
XRPV.C6L5.B2	408 μm	16.144 m	8.426 mm	11.5 GeV^2	7.926 mm	10.2 GeV^2
XRPV.D6L5.B2	372 μm	14.631 m	7.770 mm	11.9 GeV^2	7.270 mm	10.4 GeV^2

Note: upper cut-off due to aperture limitations not studied.

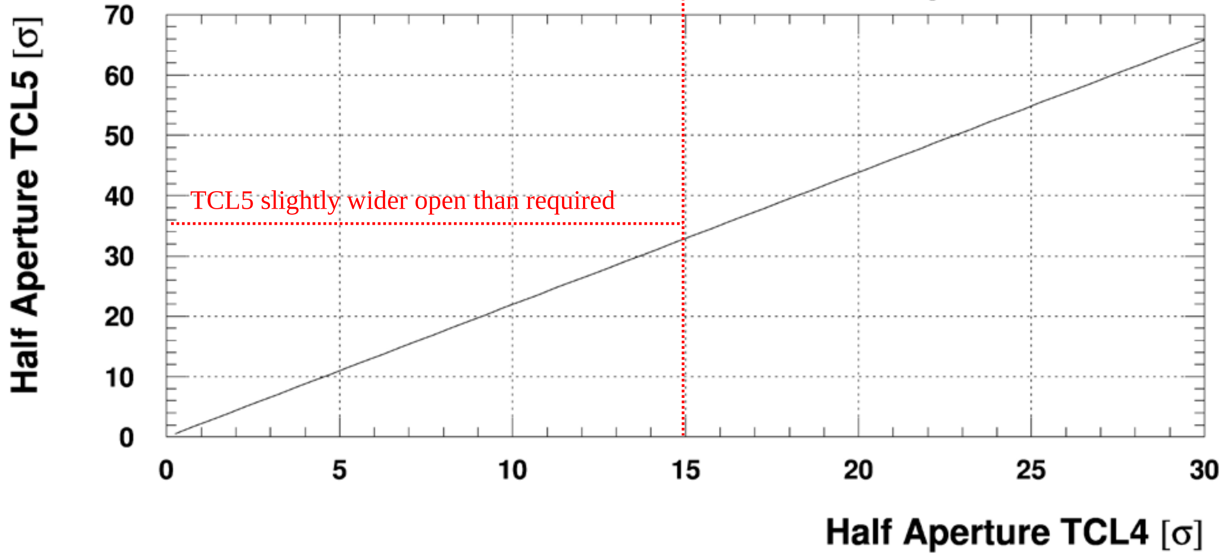
Mass Acceptance vs. TCL Apertures

$$M_{\max} = \sqrt{s}\,\frac{\sigma_{TCL4}}{D_{TCL4}} N_{TCL4}$$
$$= 86.2\,\text{GeV} \times N_{TCL4}$$



For equal mass cuts in TCL4 and TCL5:

$$N_{TCL5} = \frac{\sigma_{TCL4}}{\sigma_{TCL5}} \frac{D_{TCL5}}{D_{TCL4}} N_{TCL4}$$
$$= 2.19\, N_{TCL4}$$



A further opening of TCL4 would need studies and decision by collimation group.