CERN

Simulation studies for BLM thresholds at tertiary LHC collimators

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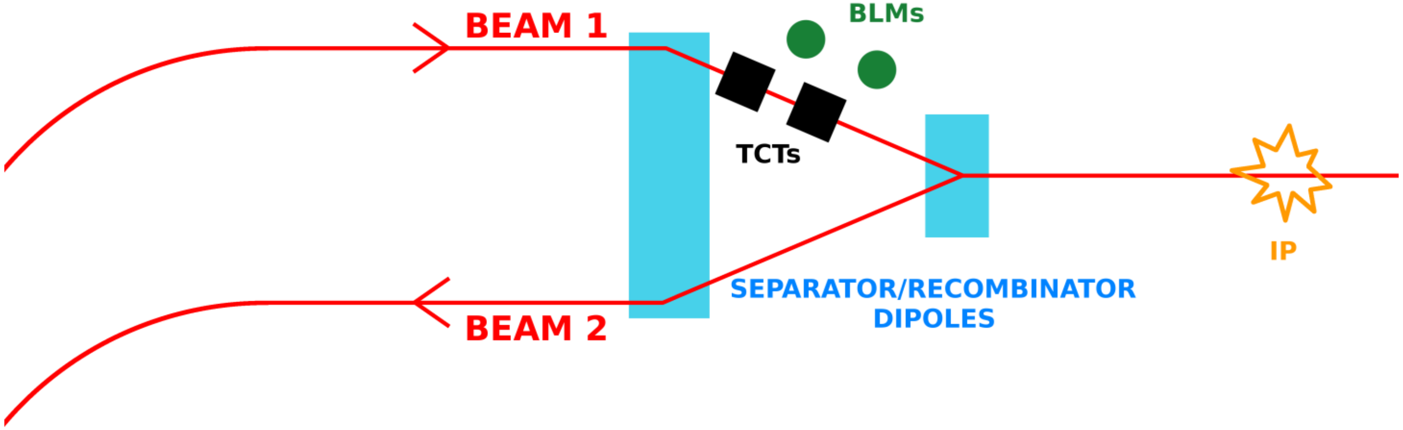
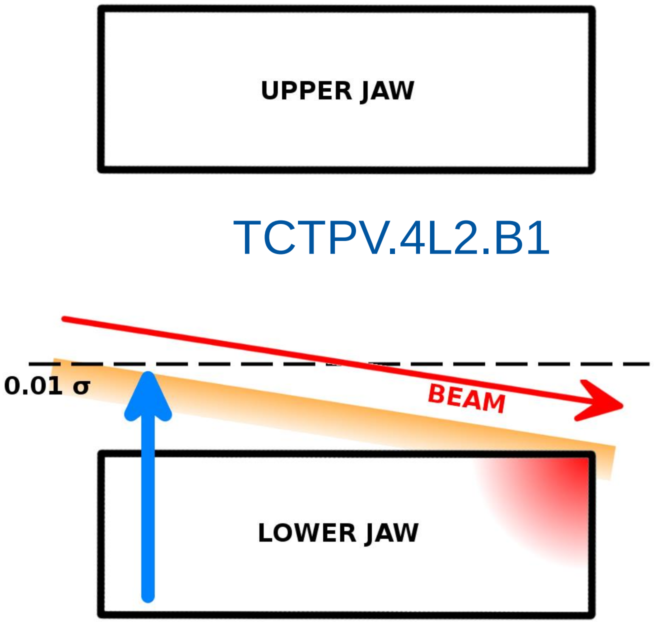
Introduction (I)



- **Review of BLM thresholds** at collimators
  - First discussions date back to 2015: https://indico.cern.ch/event/377818/
  - In particular, review of **FLUKA factors** (Gy/p) for different **materials** and dependence with **beam energy**
- Decided to start from **TCT**s
  - **Least robust** material (tungsten)
  - Being only two in a row, **cross-talk is minmised**
  - BLM families are among those **most frequently changed**

Introduction (II)

- Review of BLM thresholds based on **numerical simulations**
- Simulated scenario: direct impact on **single jaw moving towards beam** (or beam drifting towards jaw)
- **TCTPV.4L2.B1** chosen: β function on non-cleaning plane is minimized (concentrated losses)



- Three scenarios considered: **fixed jaws** aligned with closed orbit, **lower/upper jaw moving** and aligned with machine axis
- Lower jaw moving is the **most conservative case** (highest peak energy deposition, lowest BLM response)
- Two simulation steps: **cleaning** (impacts on collimator) and **energy deposition** (+ BLM signal)
- **Extensive benchmark** (qualitative and quantitative) carried out to gain confidence on simulation results

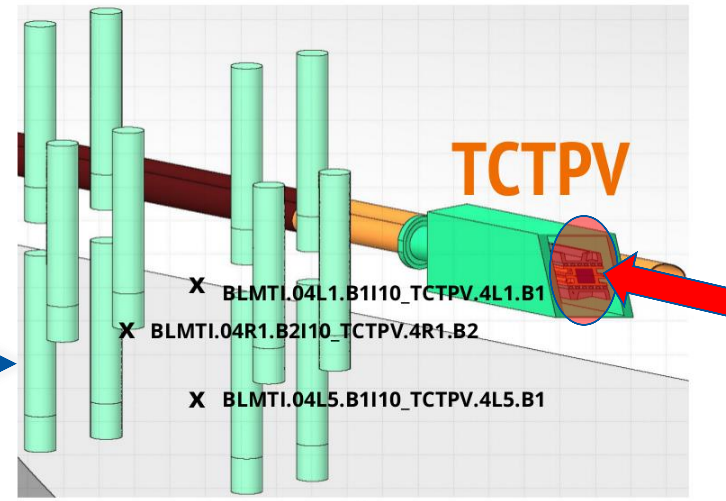
Simulation workflow

SixTrack → tracking → **Cleaning simulations**

FLUKA → interaction → **Cleaning simulations**

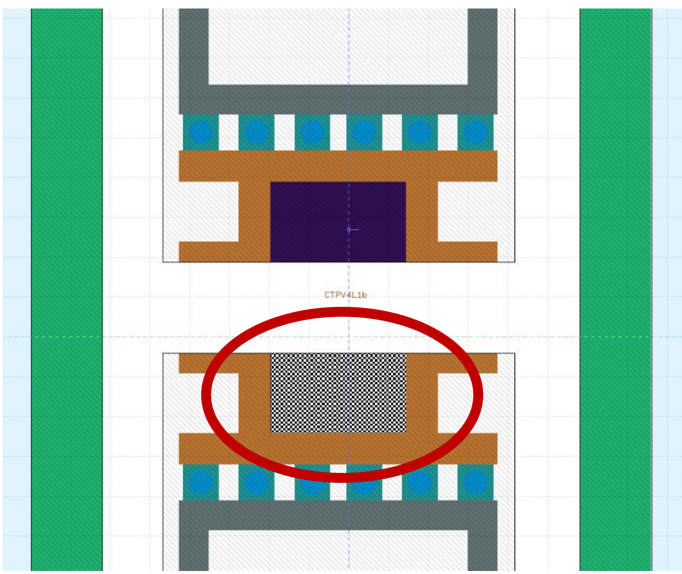
Cleaning simulations → **Impacts on collimator jaw** → **Loaded in FLUKA geometry**

Loaded in FLUKA geometry

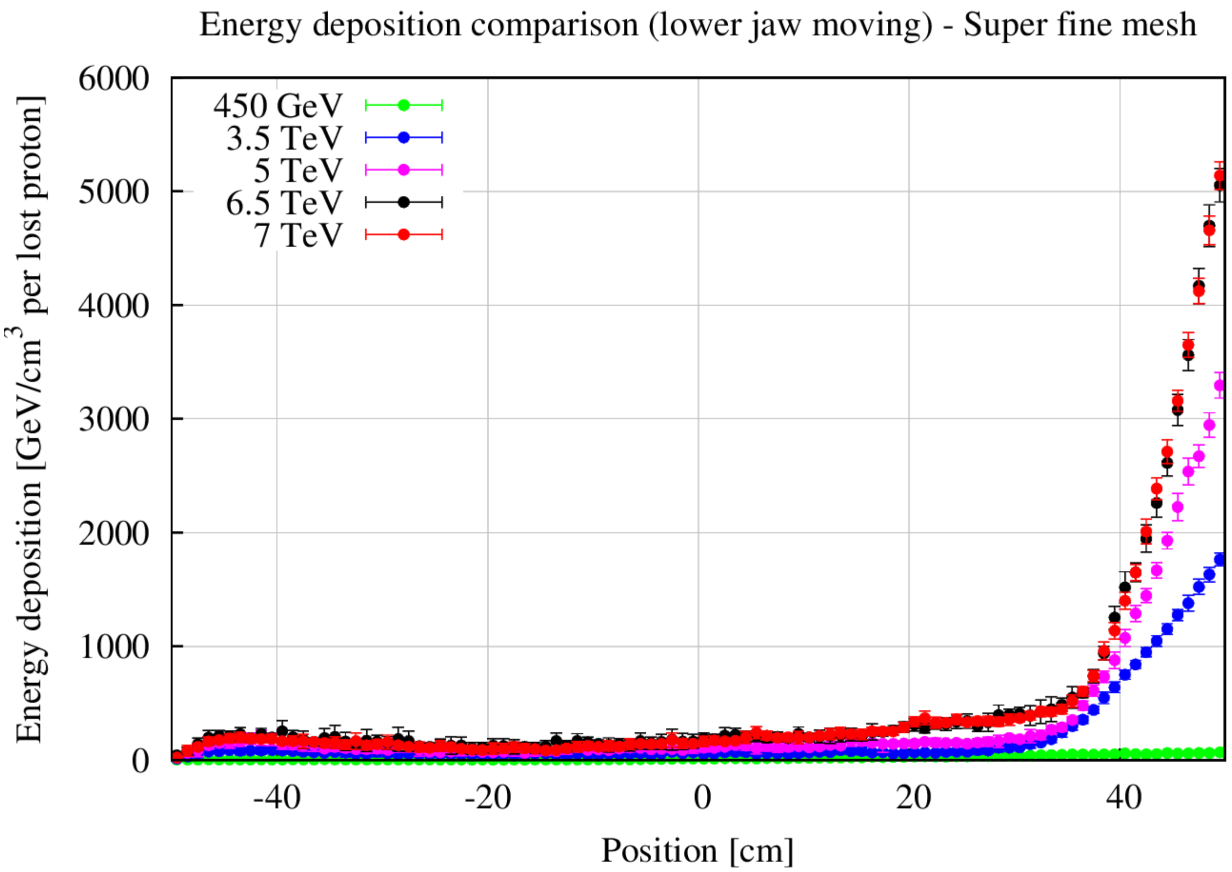


FLUKA energy deposition simulations

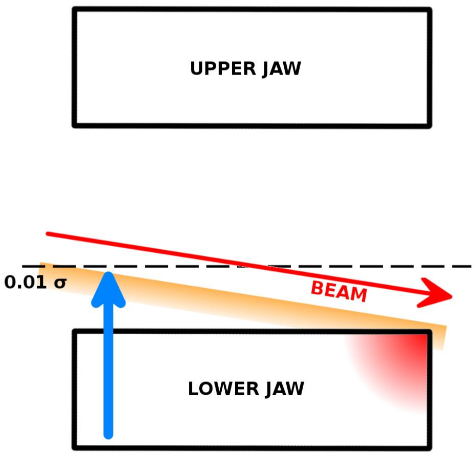
→ **Energy deposition on jaws + BLM signal**



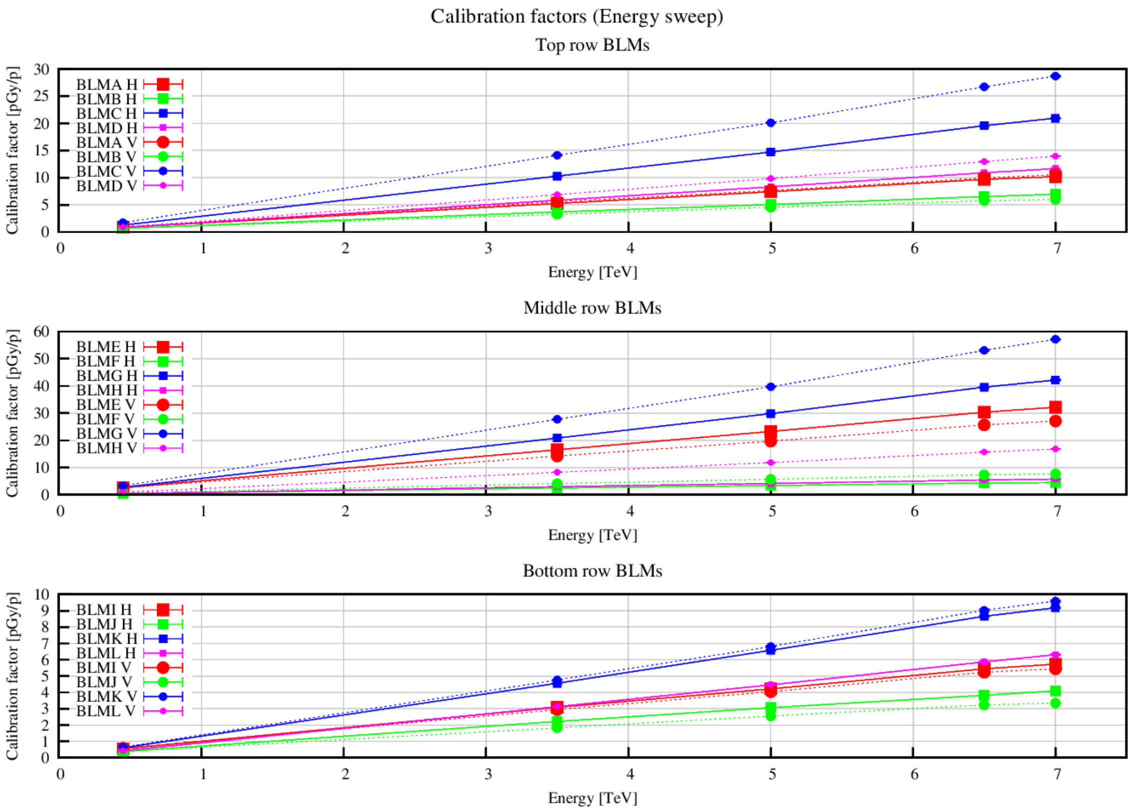
Energy sweep results (I)



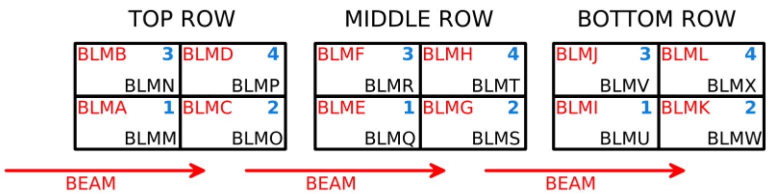
- Very **fine mesh**: 5 μm x 5 μm x 1 cm
- Required to best resolve the very fine **impact distribution**



Energy sweep results (II)



- **FLUKA BLM mesh**
  - Standardise simulation to describe wider set of configurations
  - Sensitivity analysis: dependence of BLM response on relative positions, orientation…

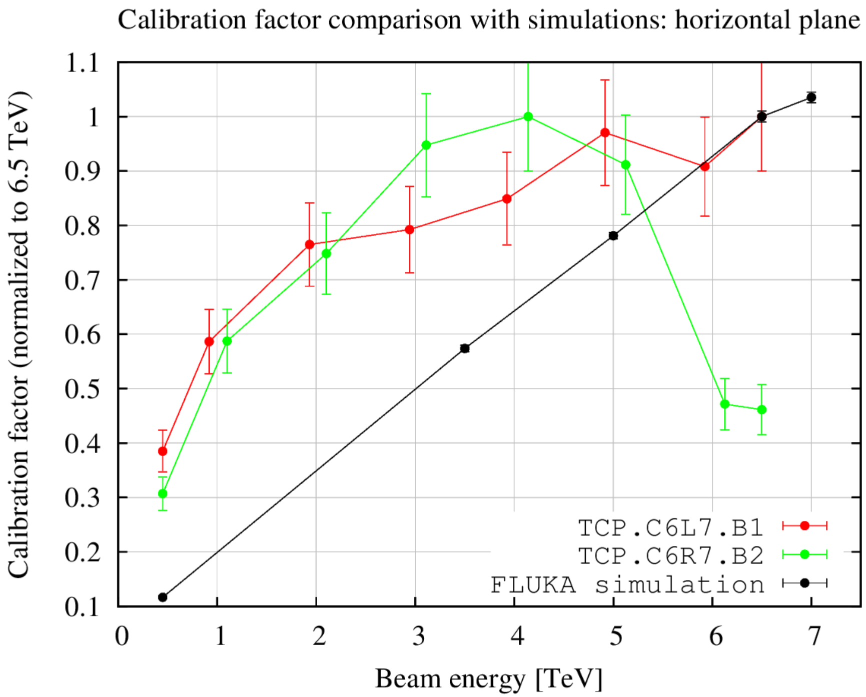


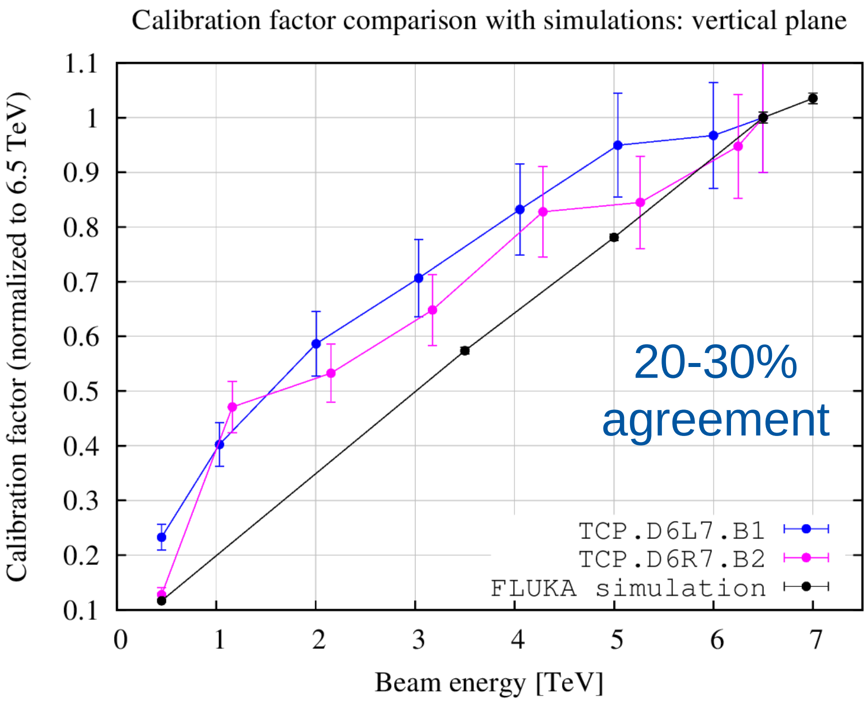
BLM label		Distance from collimator		
TCTPV	TCTPH	s [m]	x [m]	y [m]
BLMA	BLMM	0.91	0.25	0.35
BLMB	BLMN	0.91	0.51	0.35
BLMC	BLMO	1.74	0.25	0.35
BLMD	BLMP	1.74	0.51	0.35
BLME	BLMQ	0.91	0.25	0.00
BLMF	BLMR	0.91	0.51	0.00
BLMG	BLMS	1.74	0.25	0.00
BLMH	BLMT	1.74	0.51	0.00
BLMI	BLMU	0.91	0.25	-0.35
BLMJ	BLMV	0.91	0.51	-0.35
BLMK	BLMW	1.74	0.25	-0.35
BLML	BLMX	1.74	0.51	-0.35

- **Linear dependence** on beam energy
- **Middle row** (beam height) has higher response
- **Position 2** (1.74 m downstream of collimator, close to beam pipe) with **vertical orientation** has highest response

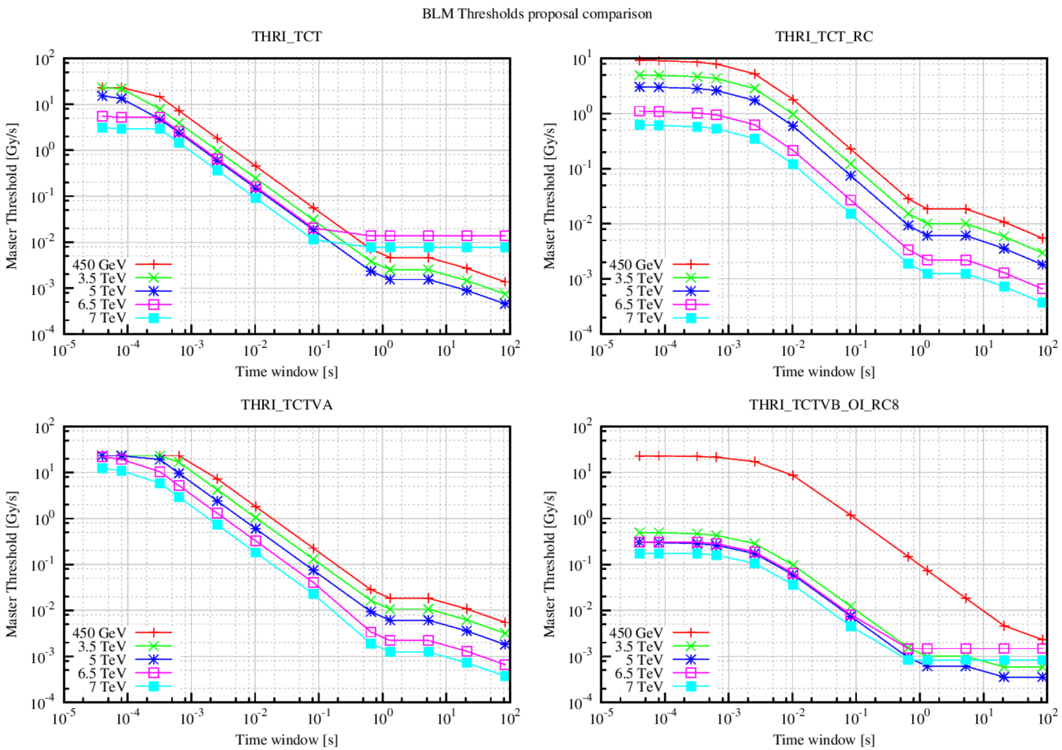
Qualitative benchmark

- Benchmark against measurements during **qualification loss maps** (24th May 2017): combined ramp+squeeze
- Primary bottleneck: **TCPs** (collimation system regularly in place)
- Qualitative benchmark of **BLM response behaviour** with beam energy





BLM thresholds review (I)



- Threshold presently deployed are reviewed with simulation results
- **Number/rate of impacting protons** allowed by present thresholds is calculated

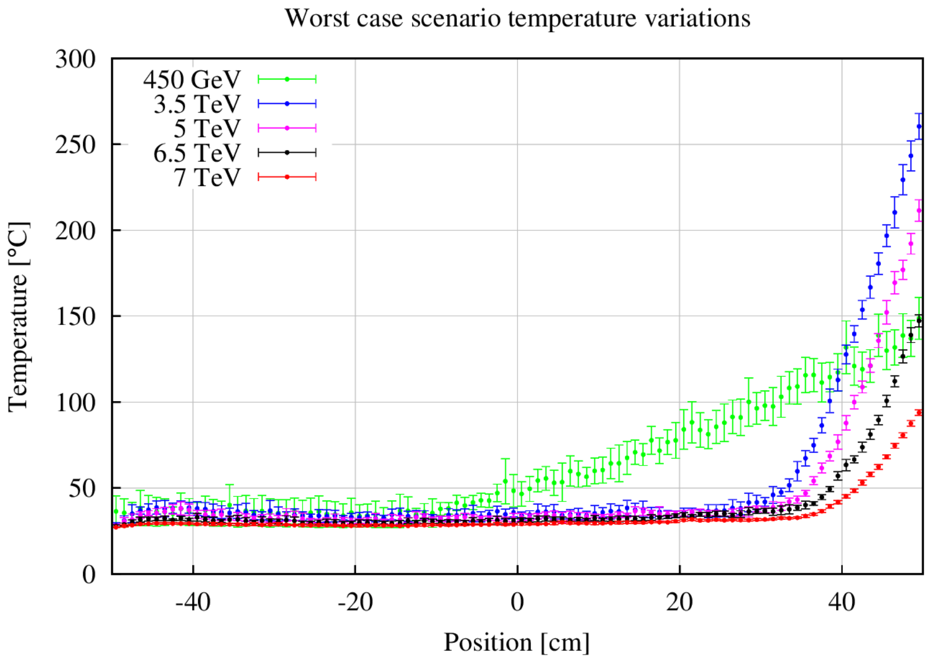
$$\mathrm{N}_p = \frac{D_{\mathrm{BLM}}^{Th} \cdot \Delta T_{\mathrm{RS}}}{\mathrm{CF}}$$

$$\mathrm{R}_p = \frac{D_{\mathrm{BLM}}^{Th}}{\mathrm{CF}}$$

- For each family, the highest number/rate of proton is considered
- For each beam energy the **highest value among all families** is considered
- **Temperature variation** (short RSs) and **power deposition** (long RSs) is calculated

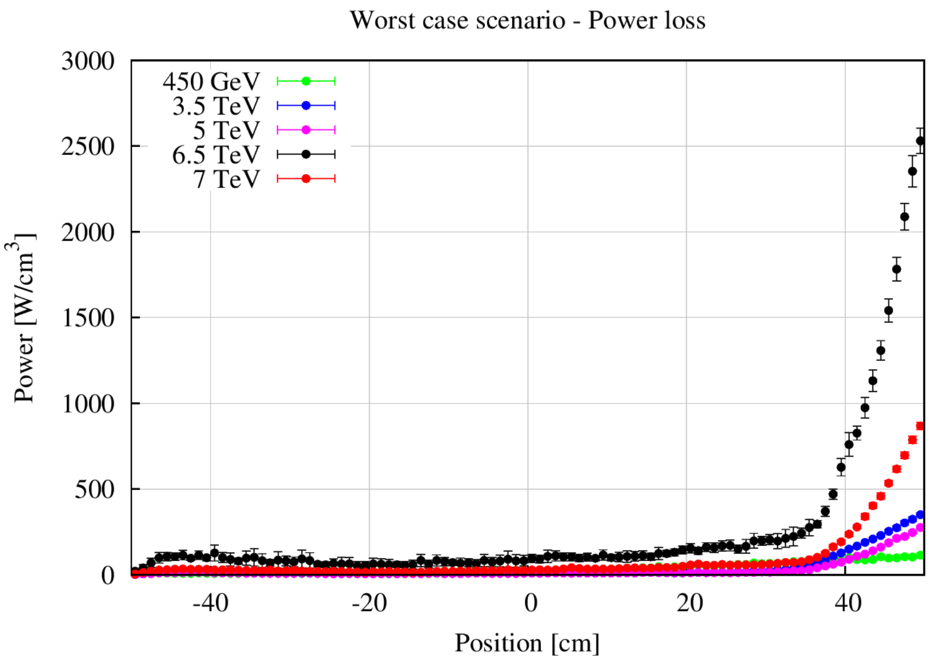
BLM thresholds review (II)

Short RSs



Not worrying

Long RSs

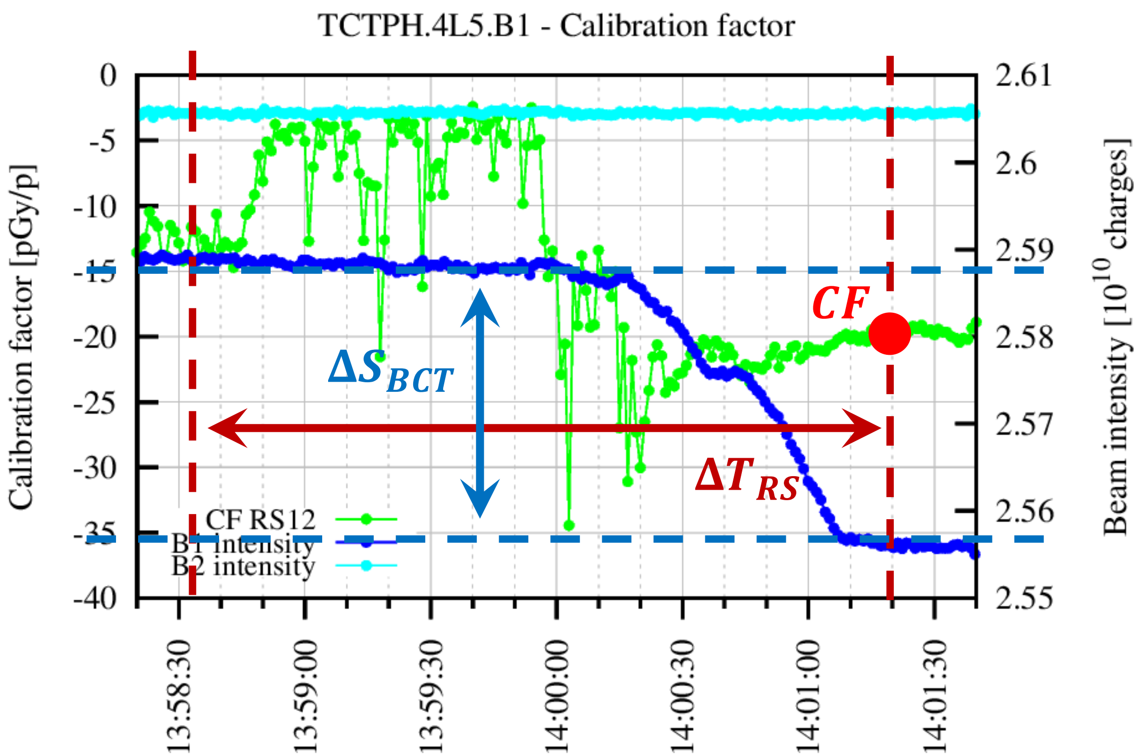


May be worrying

This scenario may bring the jaw close to plastic deformation regime (i.e. permanent deformation of the jaw)

Quantitative benchmark

- Quantitative benchmark carried out against measurements with **TCT as primary bottleneck**
- **TCTPH.4L5.B1** at 6.5 TeV (10th June 2016) and **TCTPH.4R5.B2** at 450 GeV (29th November 2016), to be compared with dedicated simulation setups

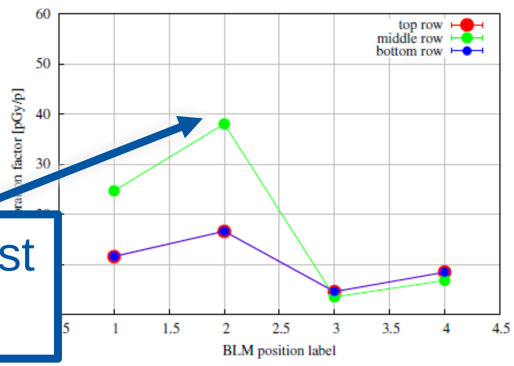
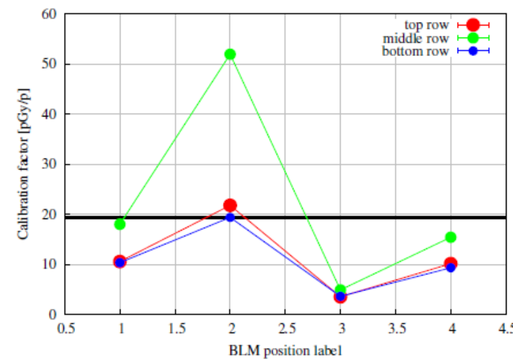
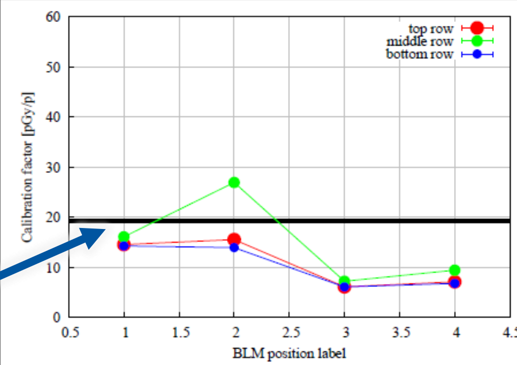


- Controlled losses produced via **beam blow up** (same as LMs)
- BLM readout from **RS12** used (more stable)
- CF chosen as single point or mean (depending on **duration and stability**)

$$\mathrm{CF} = \frac{S_{\mathrm{BLM}}}{\Delta S_{\mathrm{BCT}}} \cdot \Delta T_{\mathrm{RS}}$$

Benchmark at 6.5 TeV

Calibration factor

	Horizontal BLMs	Vertical BLMs
	0.01 σ	0.01 σ
0 μrad		
102.5 μrad		

Position with highest BLM response

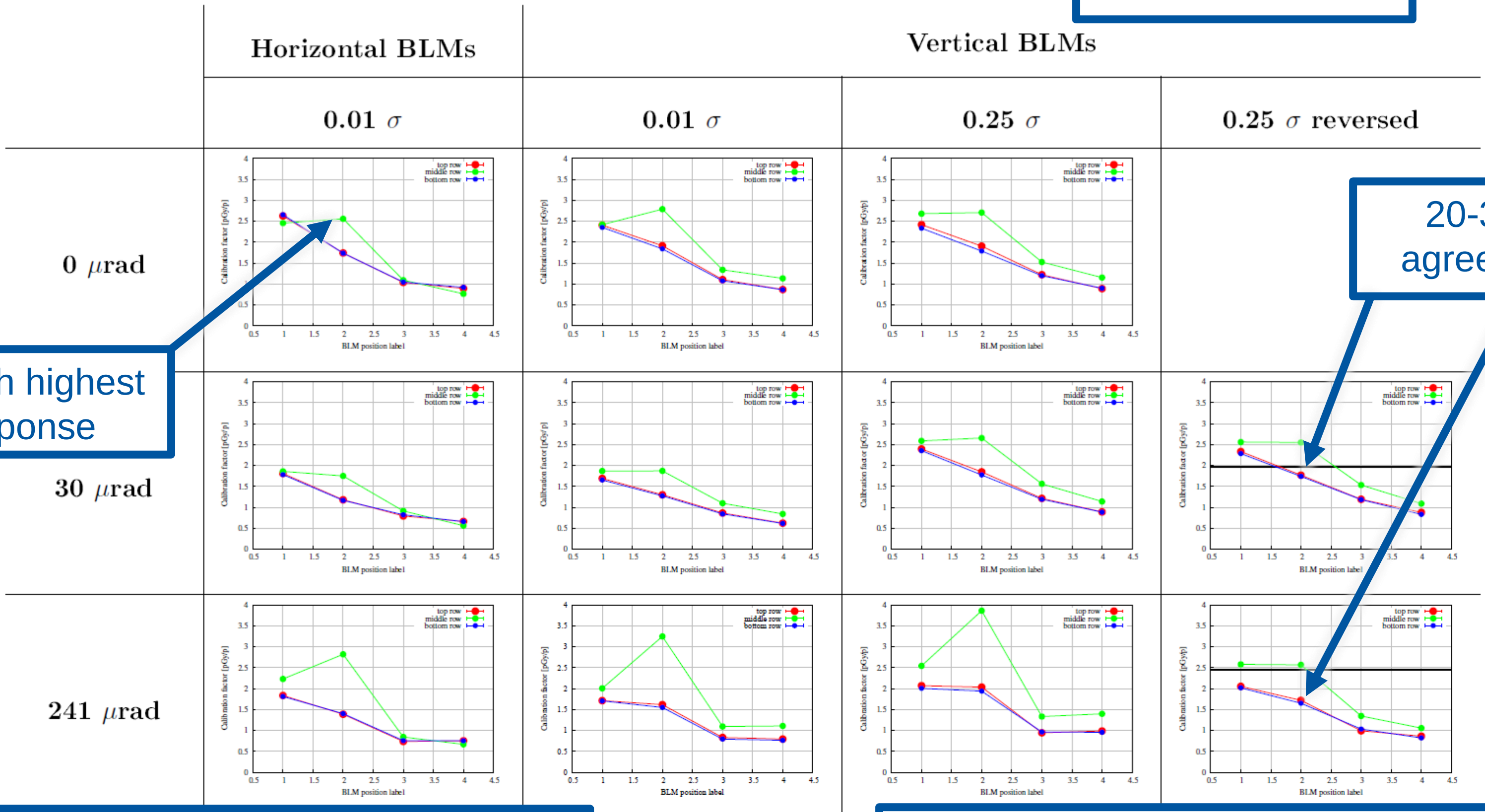
BLMQ (middle row, position 1)

20-30% agreement

Benchmark at 450 GeV (I)

Calibration factor

BLMU (bottom row, position 2)



20-30% agreement

Position with highest BLM response

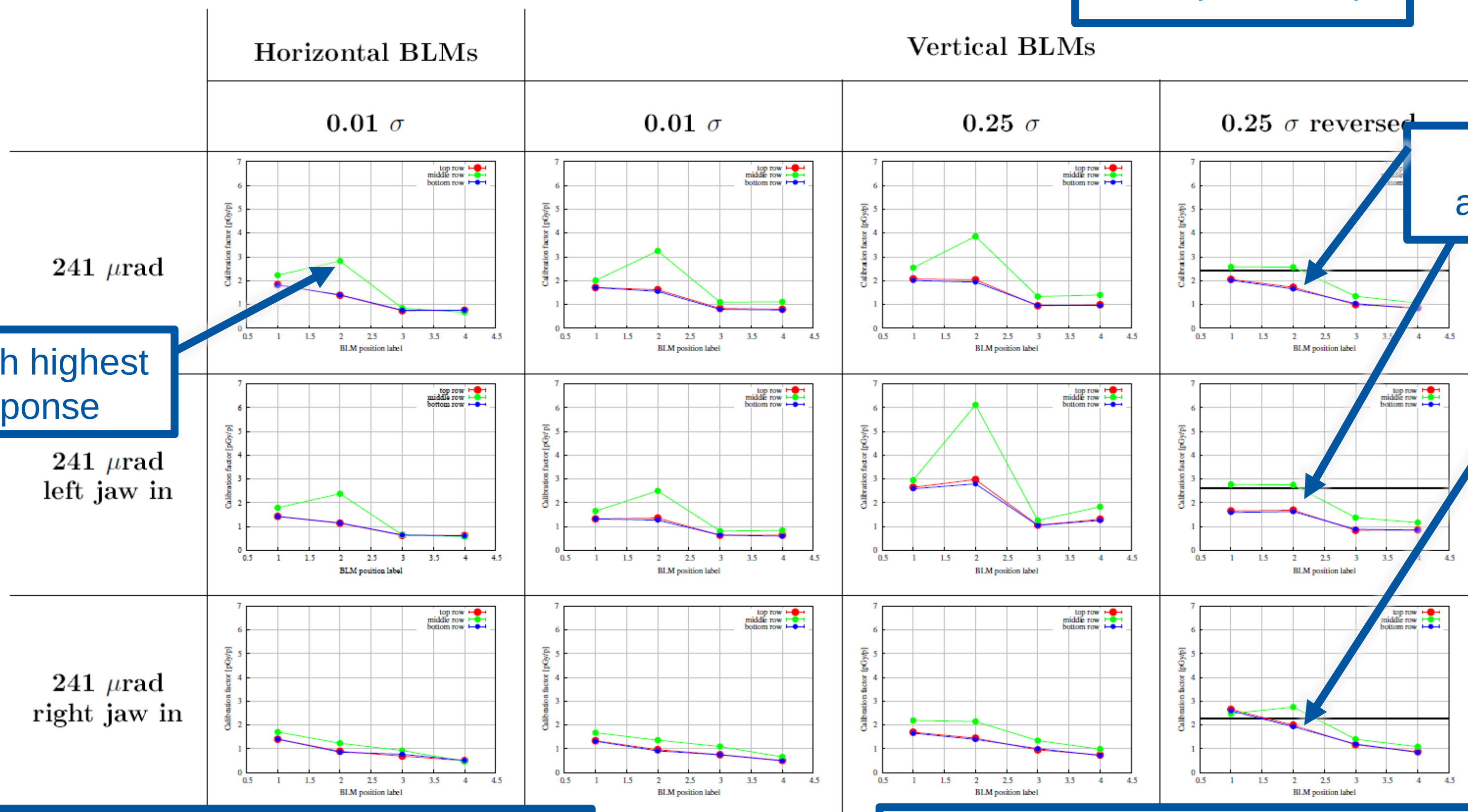
Top/bottom rows have the same response (symmetry of impacts distribution)

0.25 σ sampling has better agreement with measurements (more realistic)

Benchmark at 450 GeV (II)

Calibration factor

BLMU (bottom row, position 2)



20-30% agreement

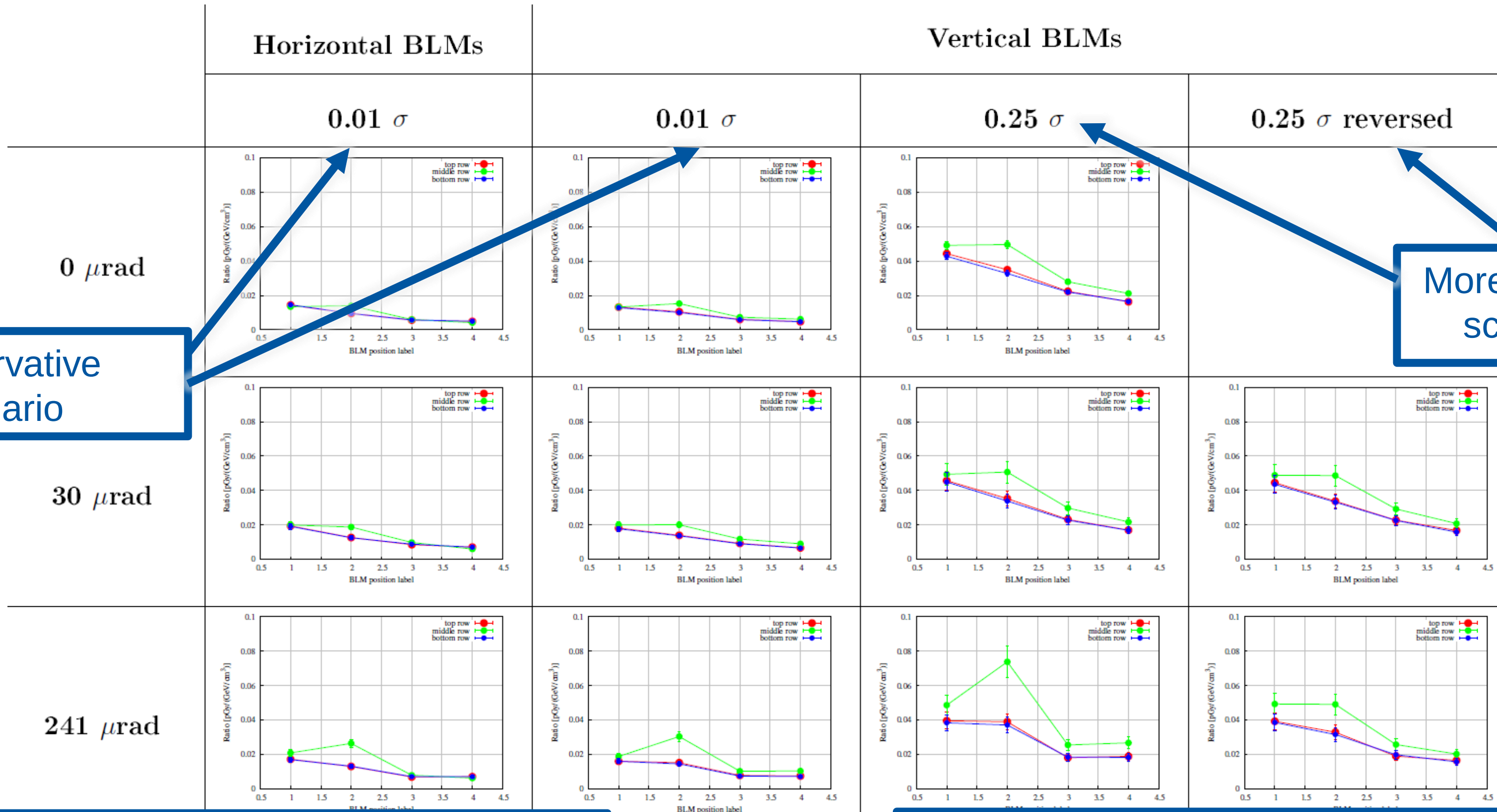
Position with highest BLM response

Behaviour of BLM response wrt which jaw is in view of the beam is reproduced

0.25 σ sampling has better agreement with measurements (more realistic)

Benchmark at 450 GeV (III)

Ratio Calibration factor / Peak energy deposition



Conservative scenario

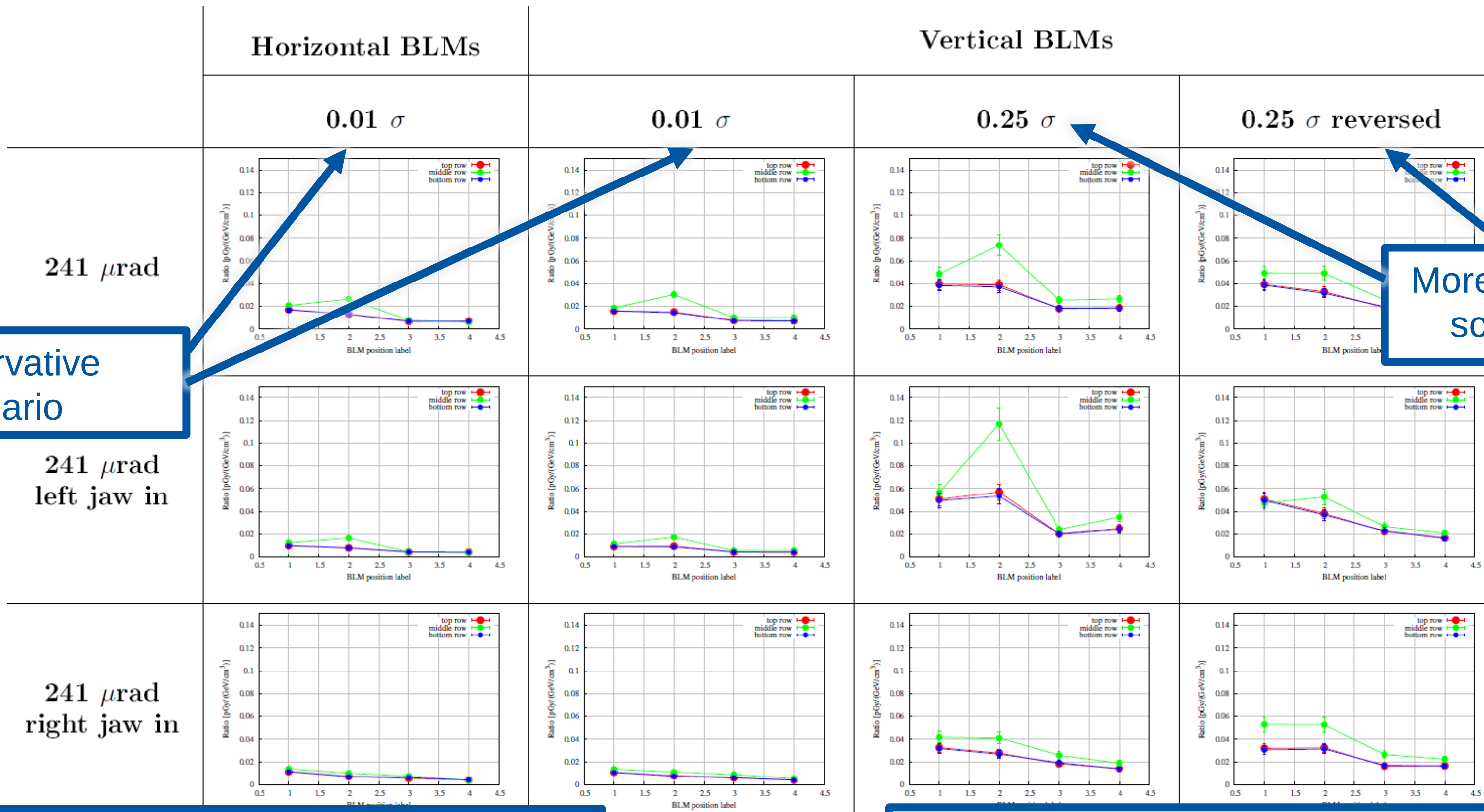
More realistic scenario

CF/peak ratio strongly depends on width of sampled halo

0.01 σ sampling used for energy sweep is more conservative

Benchmark at 450 GeV (IV)

Ratio Calibration factor / Peak energy deposition



Conservative scenario

More realistic scenario

CF/peak ratio strongly depends on width of sampled halo

0.01 σ sampling used for energy sweep is more conservative

BLM thresholds proposal (I)

- Simulation and benchmark results are combined to make a first **BLM thresholds proposal**
- BLM thresholds proposal calculated from **maximum number/rate of protons allowed** by current thresholds and **simulated CF** for each beam energy
- Proposed thresholds will allow the same peak energy deposition, no matter the beam energy
- Homogenisation achieved assuming to move all TCT BLMs to **the most favorable relative position**

BLM label		Distance from collimator		
TCTPV	**TCTPH**	s [m]	x [m]	y [m]
BLMG	BLMS	1.74	0.25	0.00

Short RSs

$$N_{p,max}|_{E_b} = \frac{E_{peak}|_{7\mathrm{TeV}} \cdot N_{p,max}|_{7\mathrm{TeV}}}{E_{peak}|_{E_b}} \equiv \frac{K_N}{E_{peak}|_{E_b}} \longrightarrow D_{\mathrm{BLM}} = \frac{\mathrm{CF}|_{E_b} \cdot N_{p,max}|_{E_b}}{\Delta T_{\mathrm{RS}}} = \frac{\mathrm{CF}|_{E_b}}{E_{peak}|_{E_b}} \cdot \frac{K_N}{\Delta T_{\mathrm{RS}}}$$

Long RSs

7 TeV leads to highest energy deposition

$$R_{p,max}|_{E_b} = \frac{E_{peak}|_{7\mathrm{TeV}} \cdot R_{p,max}|_{7\mathrm{TeV}}}{E_{peak}|_{E_b}} \equiv \frac{K_R}{E_{peak}|_{E_b}} \longrightarrow D_{\mathrm{BLM}} = \mathrm{CF}|_{E_b} \cdot N_{p,max}|_{E_b} = \frac{\mathrm{CF}|_{E_b}}{E_{peak}|_{E_b}} \cdot K_R$$

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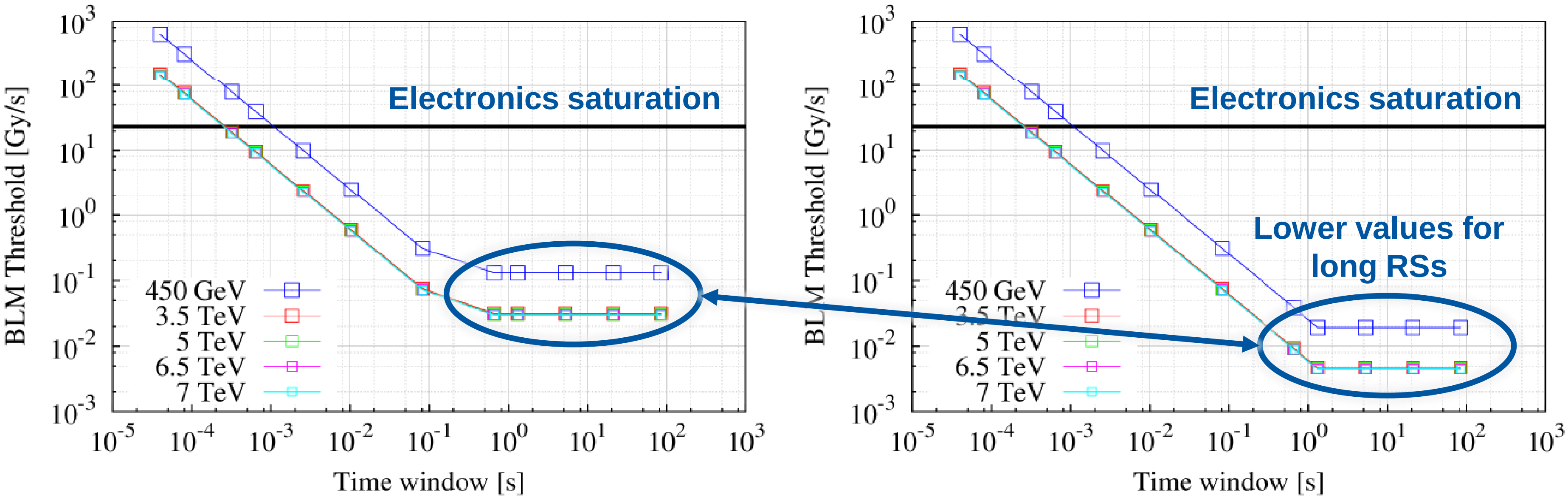
BLM thresholds proposal (II)

Safety factor 2 to take into account BLM response for H/V collimators

Limit proposal

Conservative proposal

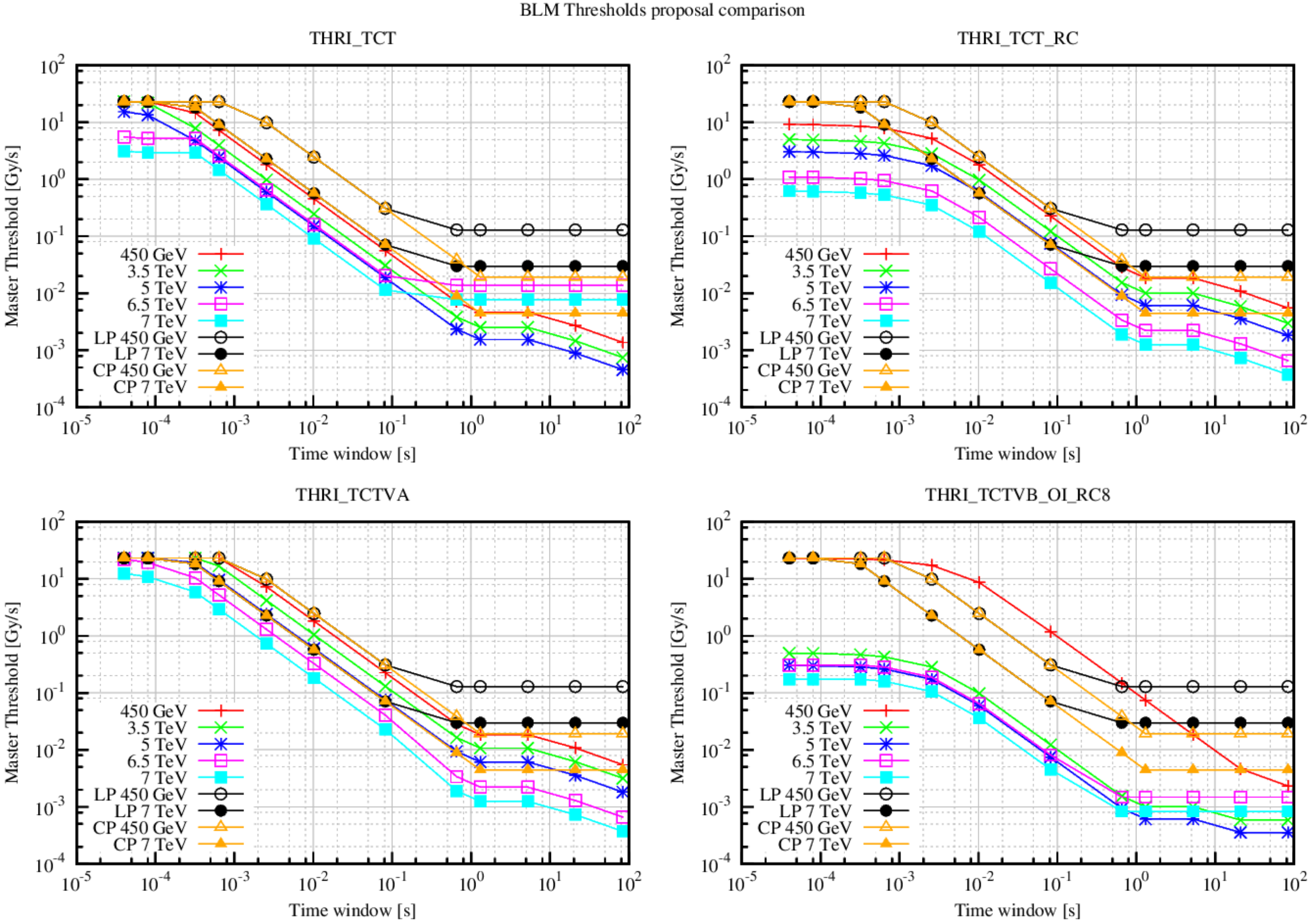


- Calculated with maximum number of protons up to RS08, with maximum proton rate from RS09 to RS12
- **More aggressive proposal (i.e. no margin wrt power deposition previously shown)**

- Calculated with maximum number of protons up to RS09, value at RS09 extended up to RS12
- **Safer proposal for long RSs**

BLM thresholds proposal (III)

Comparison between current master thresholds and proposed thresholds

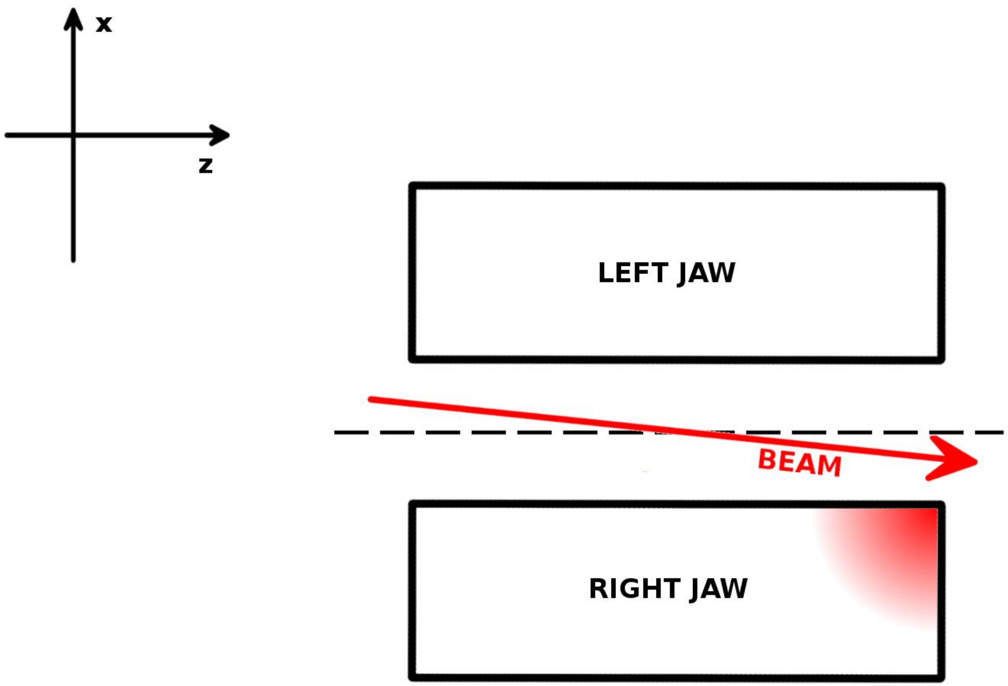


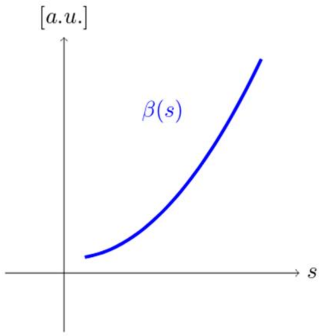
Conclusions and outlook

- Simulation studies for **BLM thresholds review** have been carried out for **TCT**s
- Simulated scenario: direct impacts on TCT, **jaw moving towards the beam** (or orbit drifting towards the jaw)
- Extensive **benchmark** (qualitative and quantitative) performed to gain confidence on simulated results
- It was possible to study the dependence of BLM response on **beam energy and relative position** with respect to collimator
- Results combined in a **proposal of new BLM thresholds**
- **Future**: compare proposed thresholds with simulation predictions and measurements in case of **regular cleaning** or in presence of **collision debris**
- **Future**: look at other **collimator families/materials**

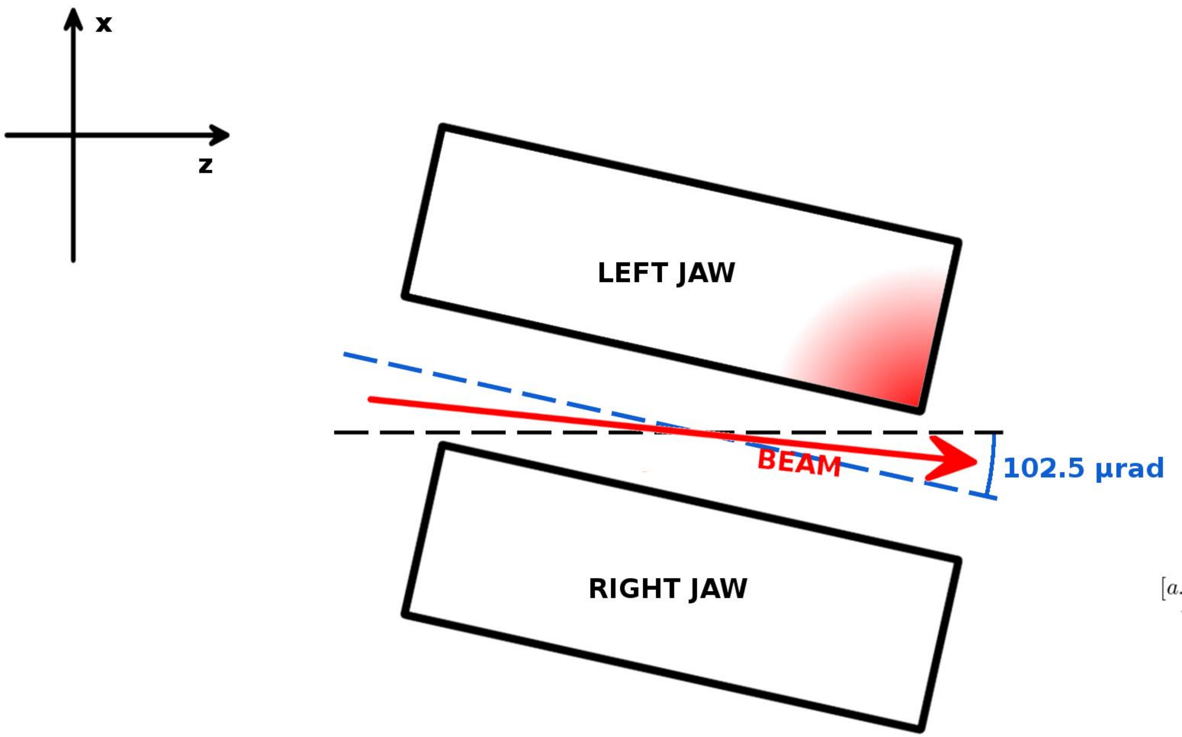
Backup slides

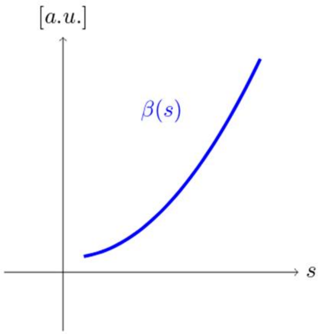
Configurations at 6.5 TeV



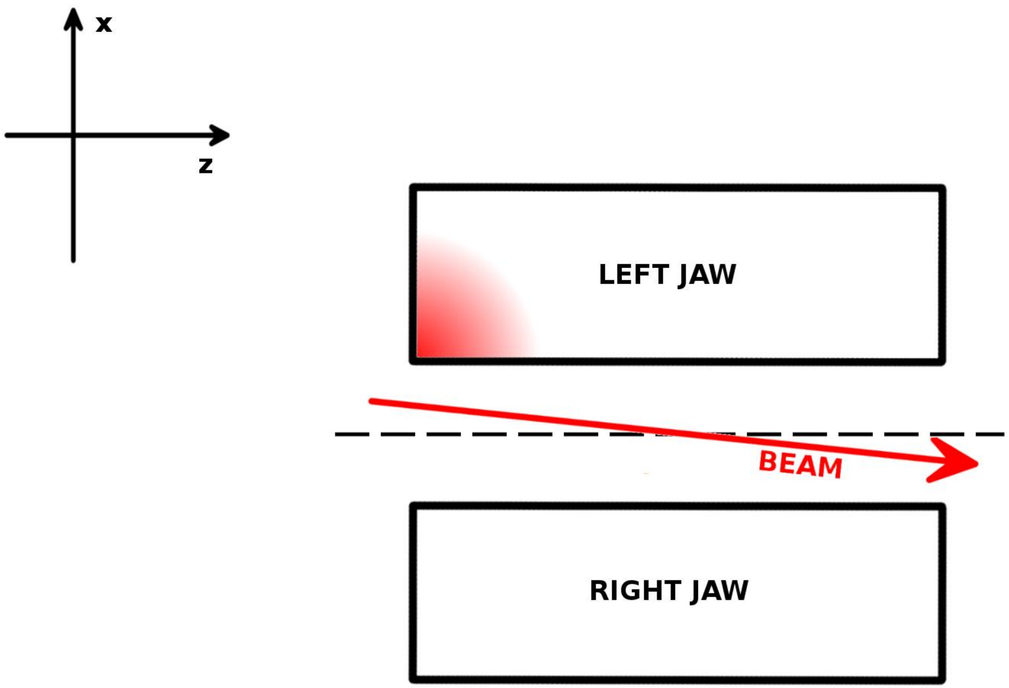


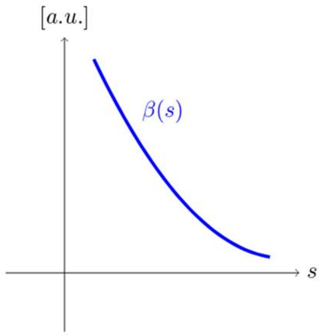
Configurations at 6.5 TeV



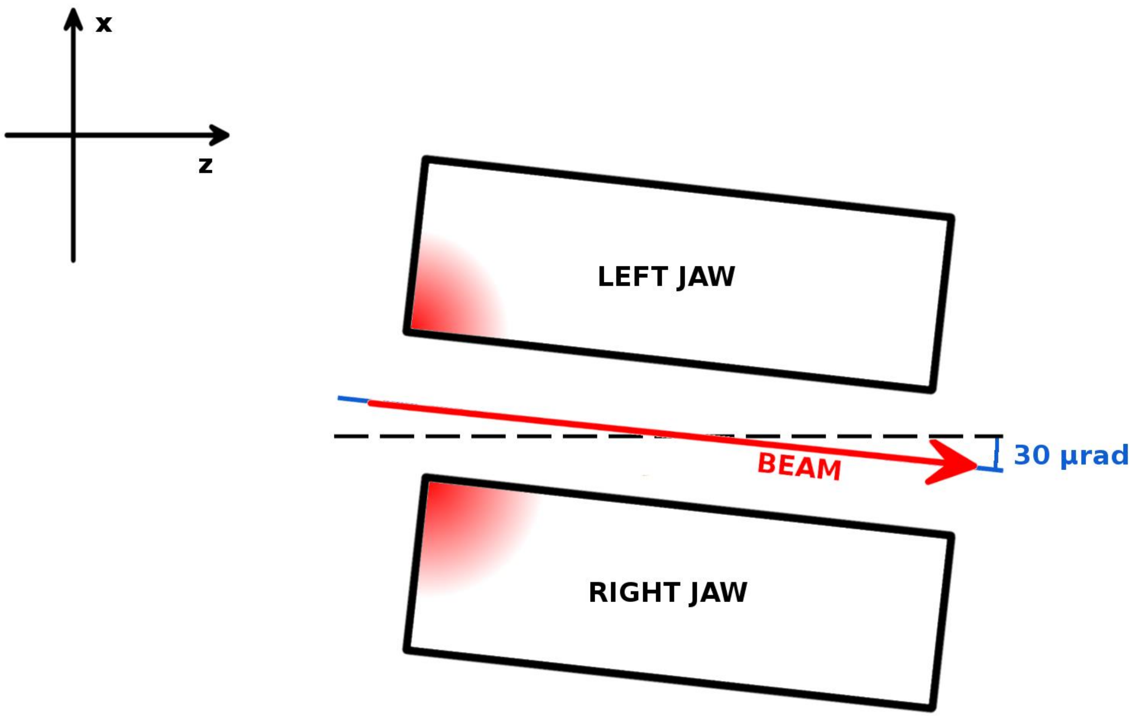


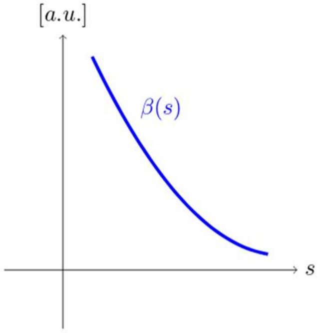
Configurations at 450 GeV



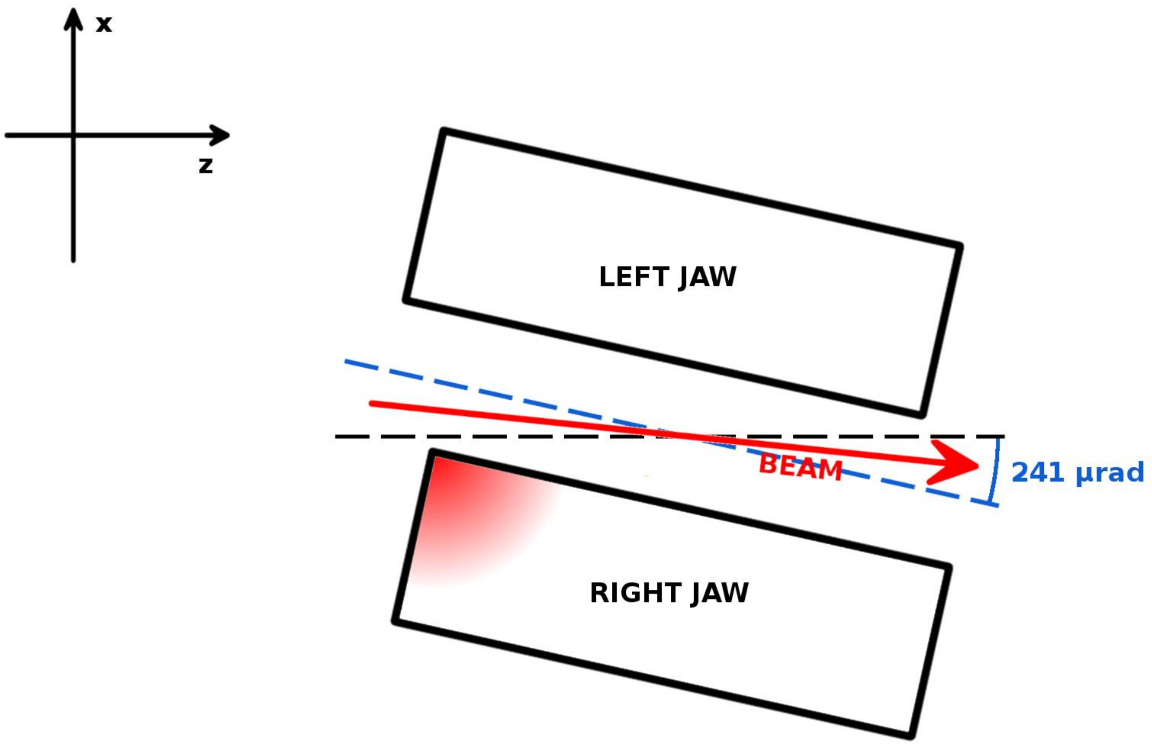


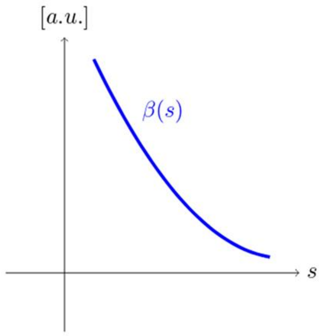
Configurations at 450 GeV





Configurations at 450 GeV





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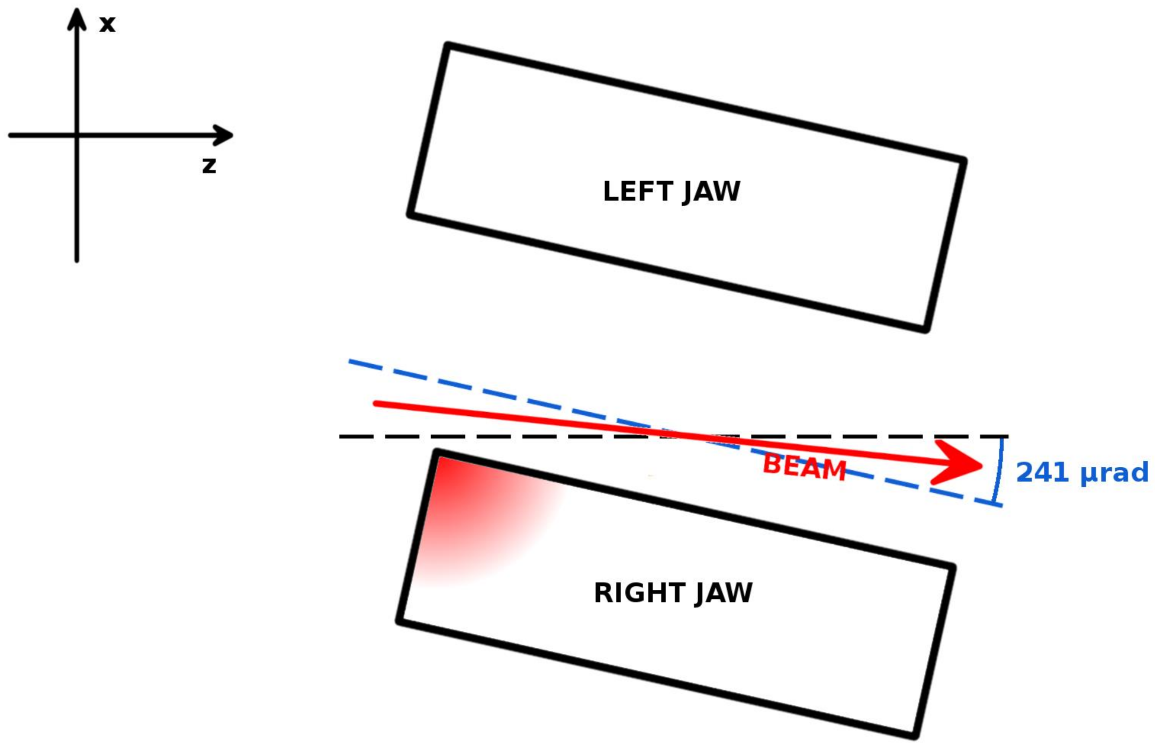

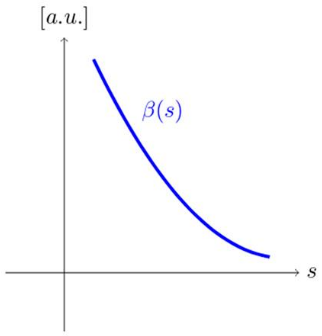

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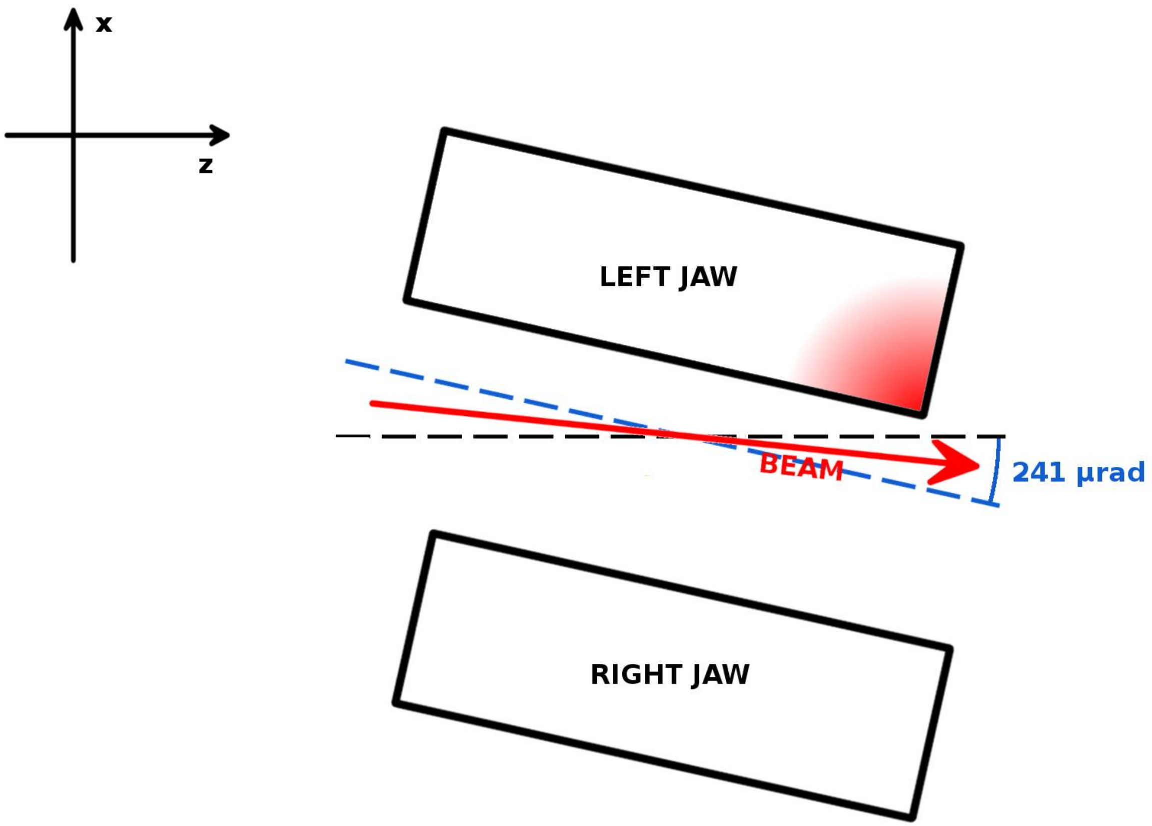
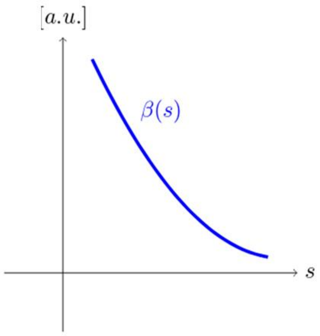
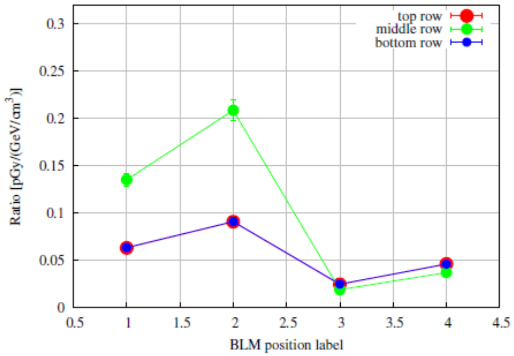
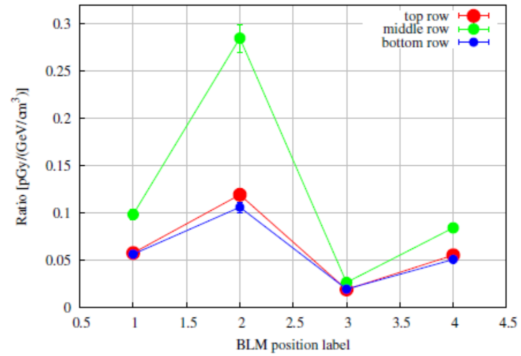
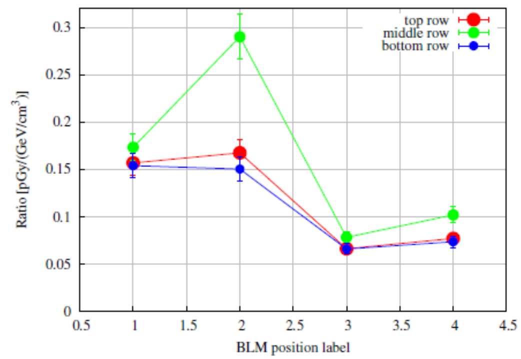




Benchmark at 6.5 TeV (II)

Ratio Calibration factor / Peak energy deposition

	Horizontal BLMs	Vertical BLMs
	$0.01\ \sigma$	$0.01\ \sigma$
$0\ \mu$rad		
$102.5\ \mu$rad	No relevant changes of ratio with tilt angle	

BLM thresholds proposal (IV)

These thresholds allow the same peak energy deposition no matter the beam energy