Requirements for beam halo population measurements

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On behalf of WP5

Acknowledgments to:

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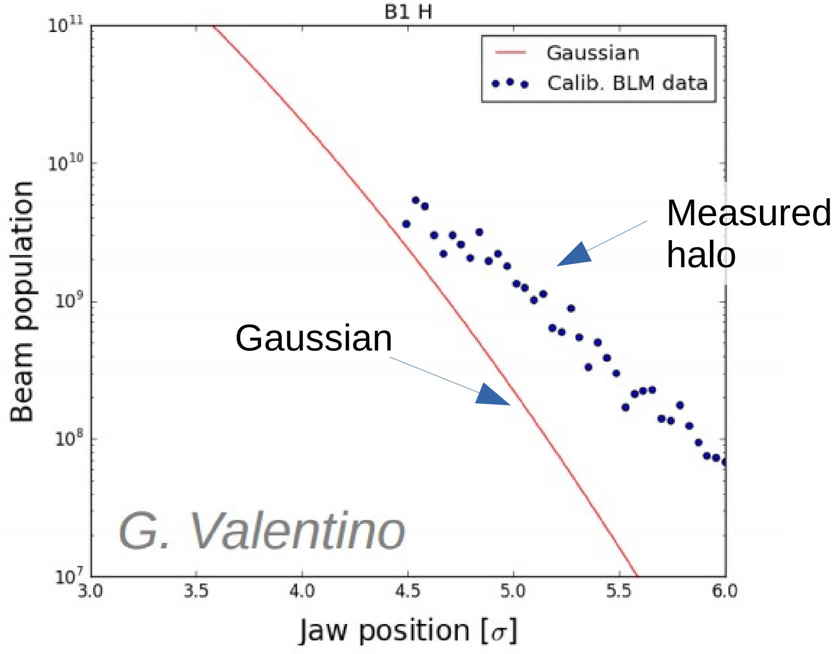
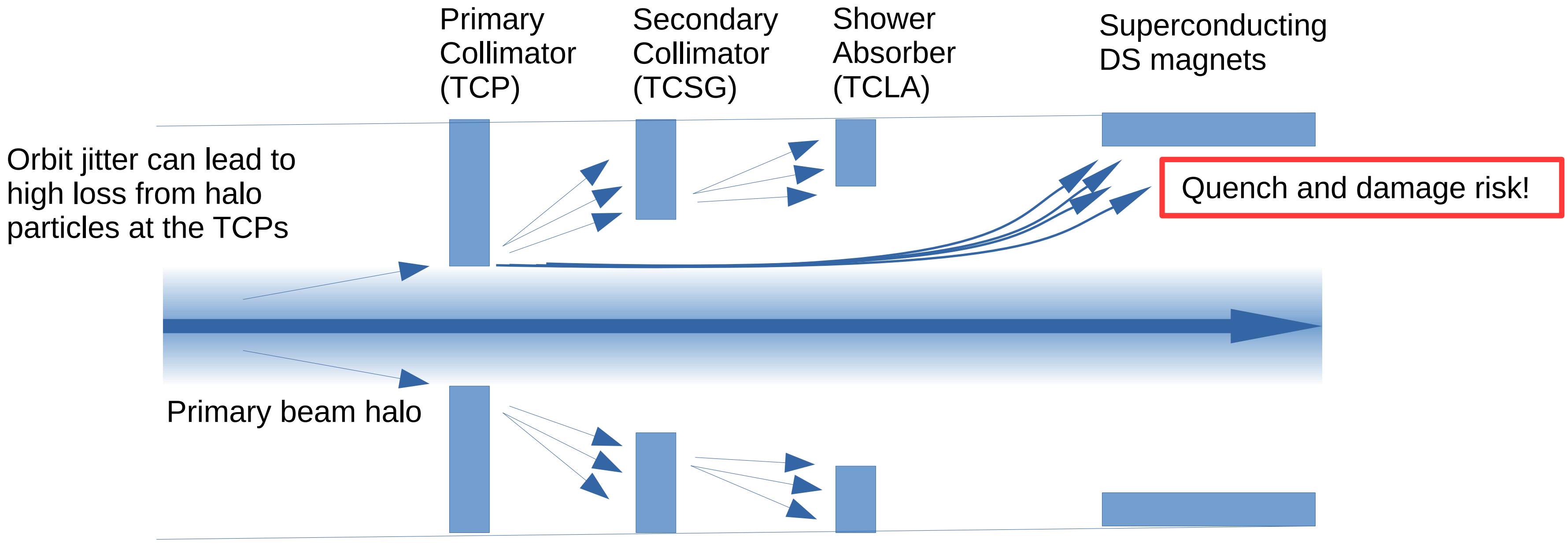
Introduction

- **Stored beam energy** in HL-LHC approximately **700 MJ per beam**
- LHC measurements: significant fraction (~5%) stored in beam halo
- Scaling by total intensity LHC to HL-LHC → **beam halo carries ~ 35 MJ**
- Fast failure scenarios can cause **very sudden orbit shifts**
- Induced high beam loss: affect operational efficiency, **potential collimator damage**!
- Solution: Hollow Electron Lens (HEL) to remove particles from beam halo

Collimator scan

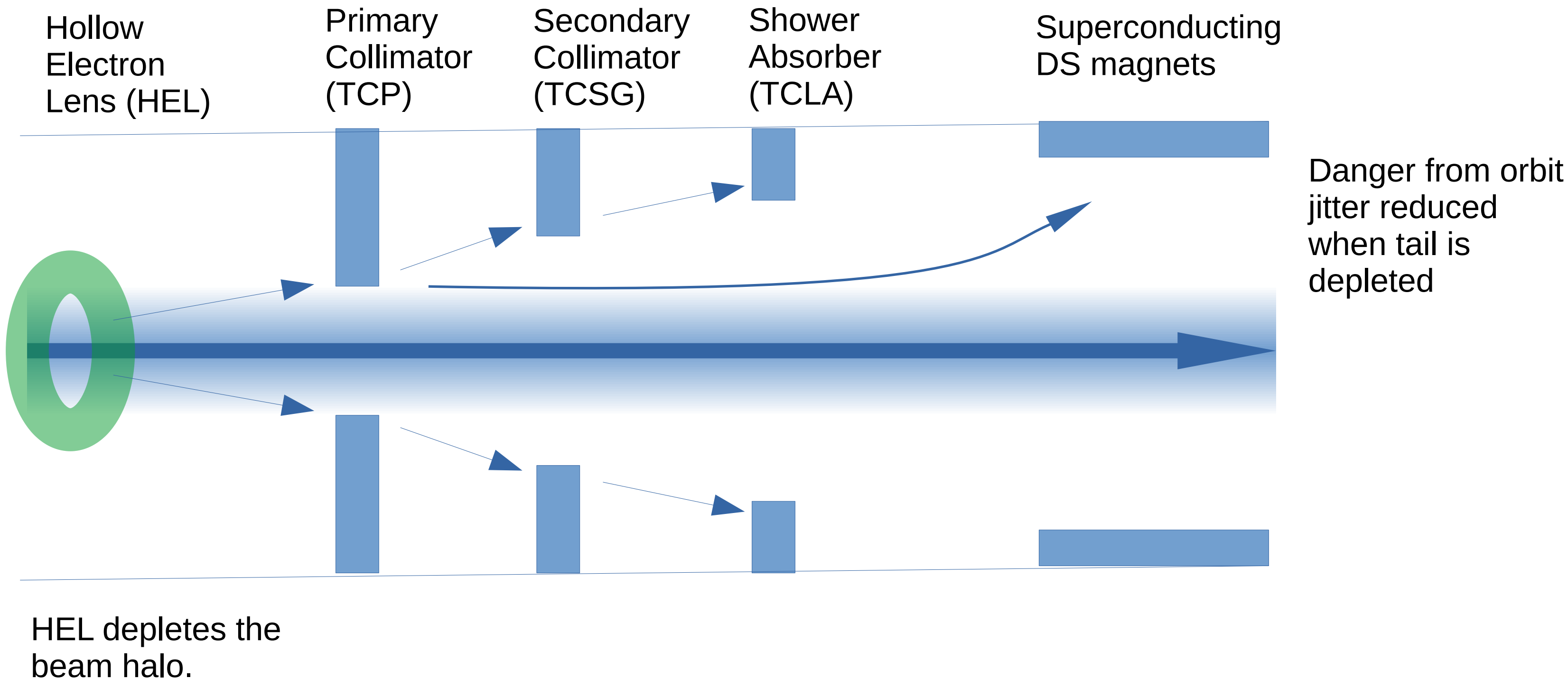


Introduction
LHC Collimation System

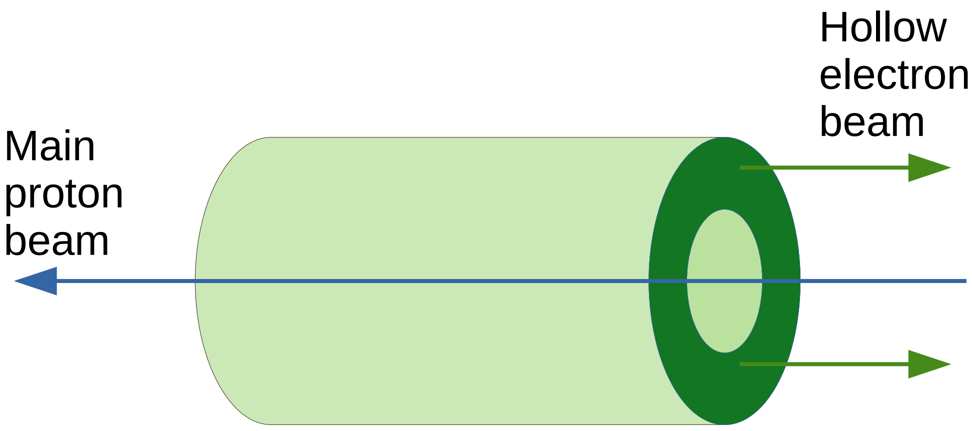


Introduction

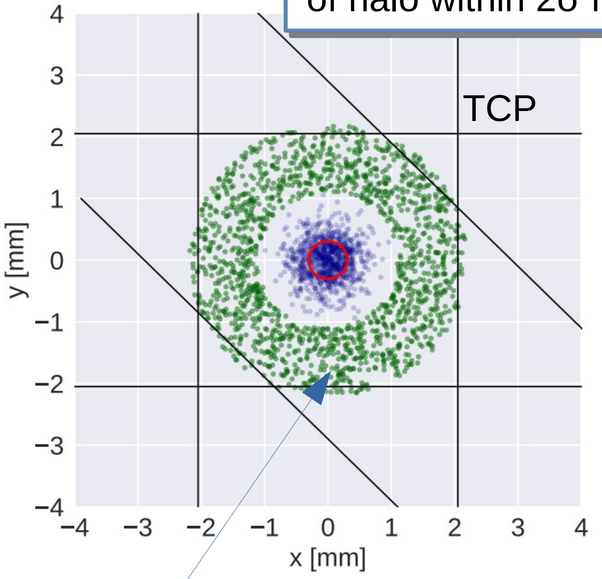
HL-LHC Collimation System with Hollow Electron Lens



Concept of hollow electron lenses

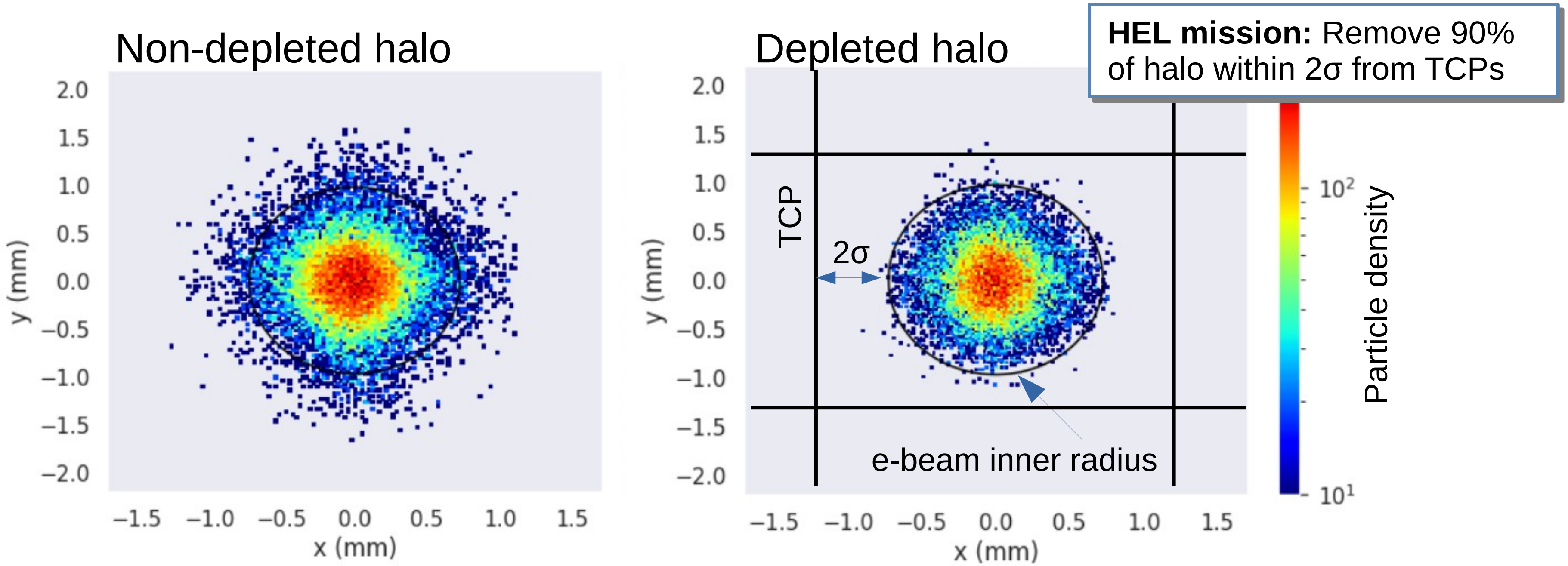


HEL mission: Remove 90% of halo within 2σ from TCPs



Tail particles experience kick from electromagnetic field → remove particles from the beam halo

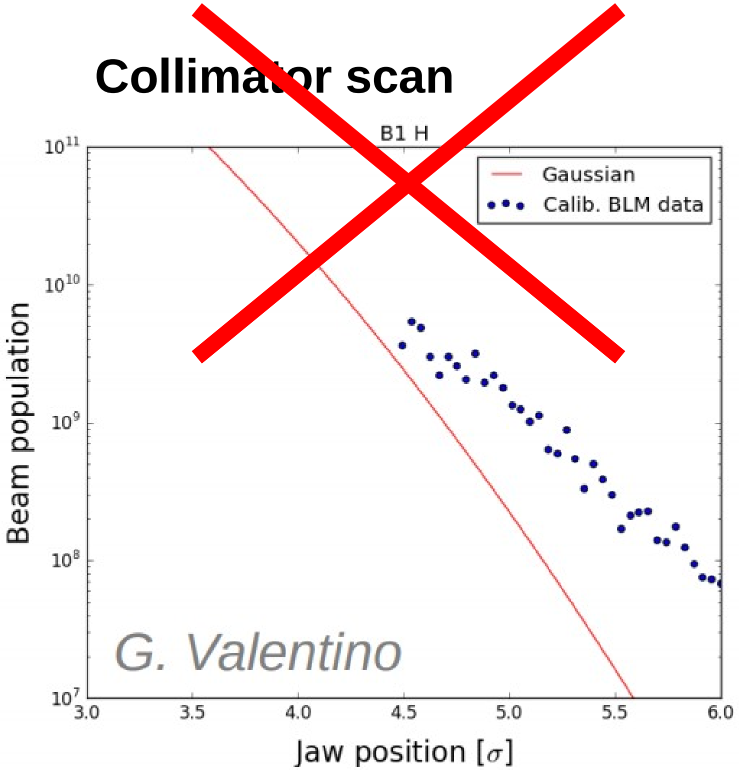
Halo measurements in HEL operation



- **Beam halo population measurements** needed to
  - Commission and evaluate performance of HEL
  - Ensure that operational safety/efficiency not jeopardized by too high halo population → interlock
- Imperative requirement: non-destructive measurement
- Versatile enough to cover all relevant configurations

Halo measurement options

Collimator scan



- Destructive and difficult to calibrate
- Not suited for monitoring during operation

Coronograph

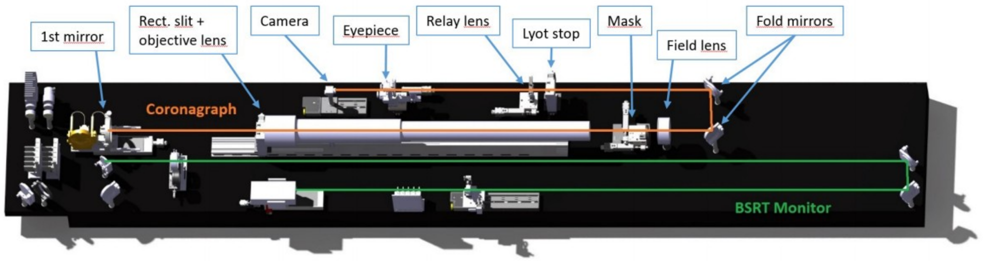


Figure 4: 3D drawing of the LHC halo monitor.

Courtesy of A. Goldblatt *et al.*,
MOPG74, Proceedings of IBIC2016

- Based on synchrotron light
- Non-destructive
- Continuous monitoring
- Challenge: diffraction. See next presentation by E. Bravin

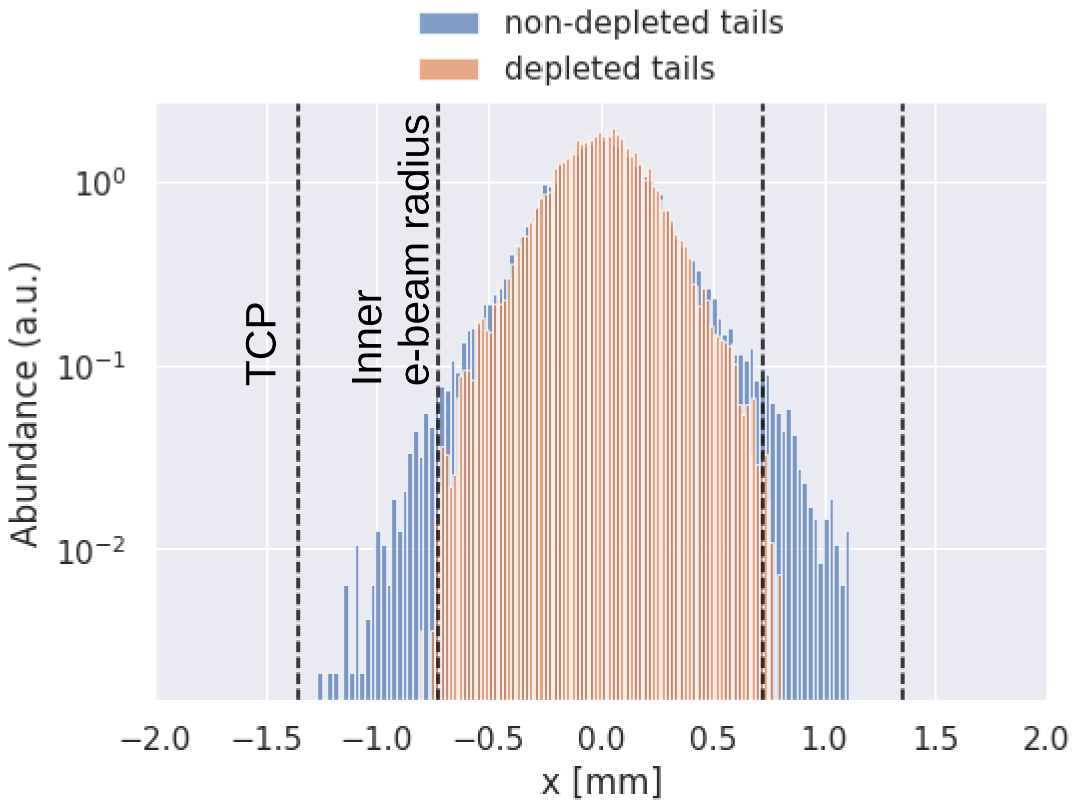
Possible operational configurations

Tail clearance	TCP half gap (σ_{ref})	ε_N (µm rad)	Radial range in real beam size	Radial range** to measure (mm)
Max. possible	6.7	2.5	3.6* to 6.7	0.9 – 1.7 (x) 1.3 – 2.3 (y)
Min. required			4.7 to 6.7	1.2 – 1.7 (x) 1.6 – 2.3 (y)
Max. possible	8.5		4.25 to 8.5	1.1 – 2.2 (x) 1.5 – 3.0 (y)
Min. required			6.5 to 8.5	1.7 – 2.2 (x) 2.3 – 3.0 (y)

σ_{ref} corresponds to the RMS beam size with 2.5 µm rad normalized emittance
*) corresponds to the min. achievable inner e-beam radius of 1.1 mm
**) beam size at 7TeV at BSRTR.5R4.B1

- Further scenarios for MDs and machine studies may be of interest as well
- Measurements at injection are also considered
- Flexibility needed also for smaller emittances
- What range can be reached?

Desired interlock approach

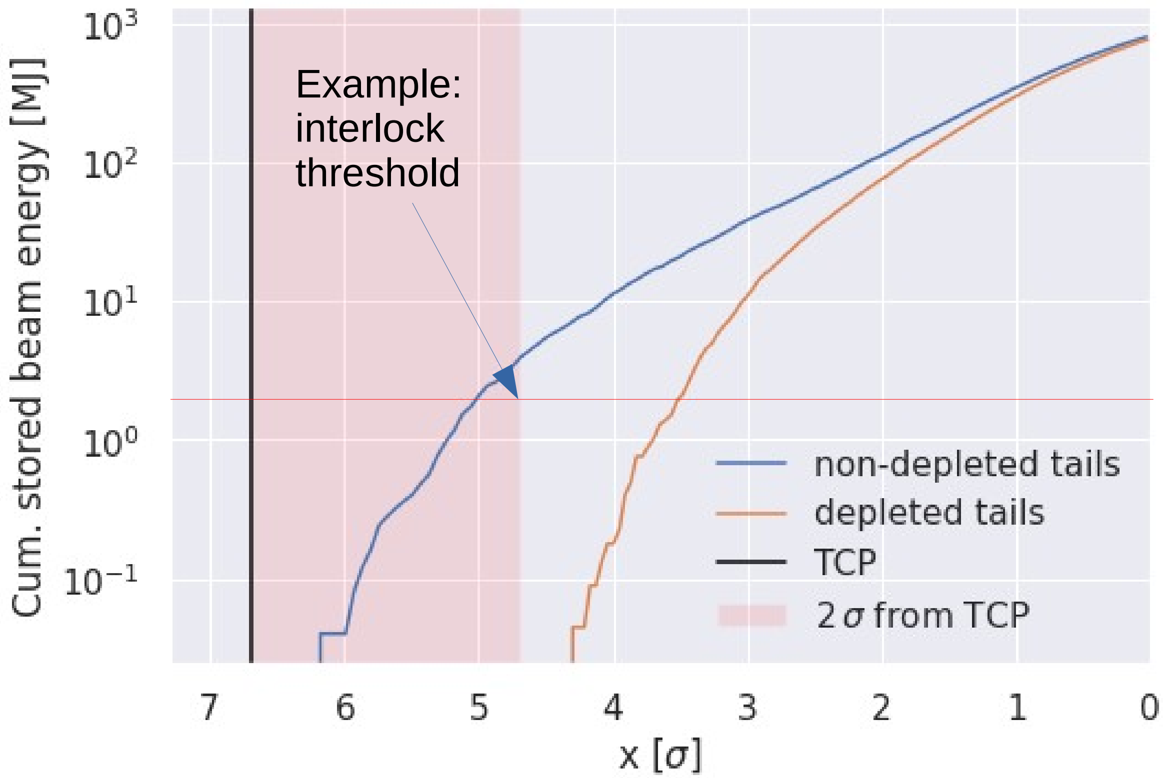


- Failure scenarios cause shifts of the beam orbit in either of the transverse planes
- Integrated halo population in each plane *u*=*x*,*y* must not exceed a certain threshold *T*

$$\mathcal{T} > \int_{u_{\mathrm{TCP}}-2\,\sigma}^{u_{\mathrm{TCP}}} |\rho(u)|\,\mathrm{d}u$$

where *ρ(u)* is the particle density

Desired interlock

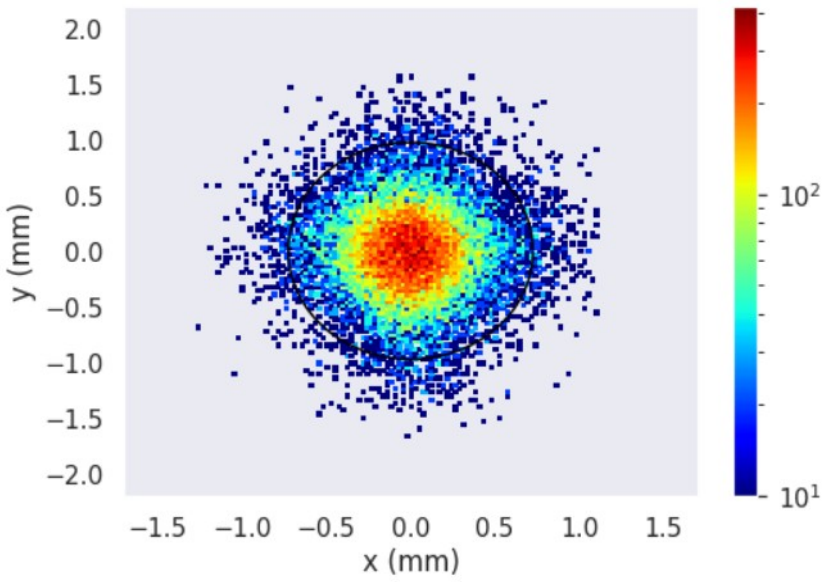


Possible approach:

- **Interlock on cumulative stored beam energy** within *nσ* from either of the two TCPs (horizontal / vertical)
- Must be able to integrate over the energy stored above a given transverse amplitude

Conclusions

- Non-destructive halo monitoring: crucial for safe operation of HL-LHC collimation system
- Flexibility in operation needed: measure with different TCP and HEL settings
- Possible interlocks based on measured stored beam energy between TCP and *nσ*
- For studies aim to have a 2D image that can be integrated



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