ATLAS Forward Proton

Pot Heating Studies

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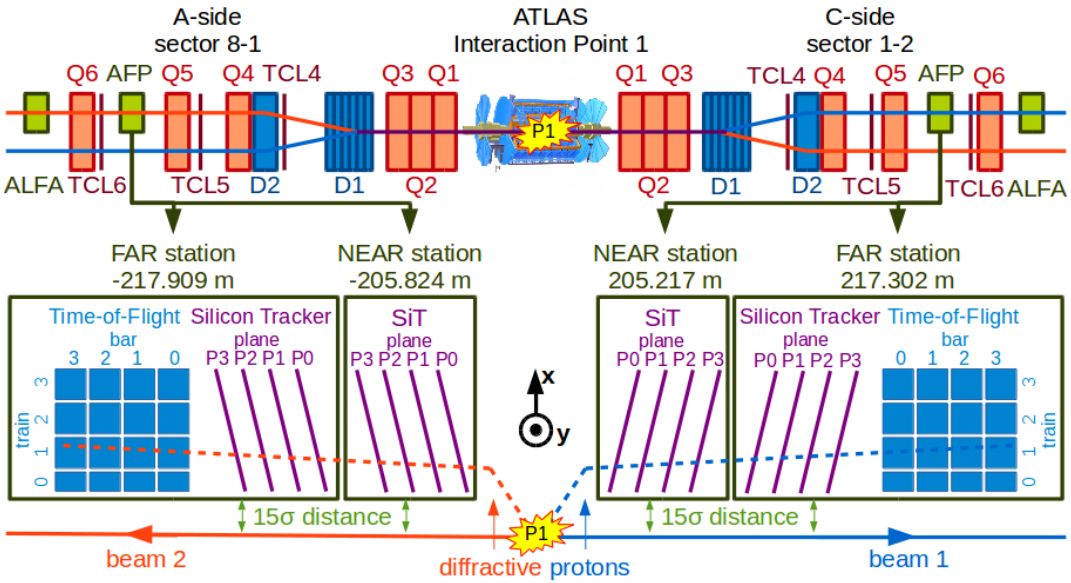
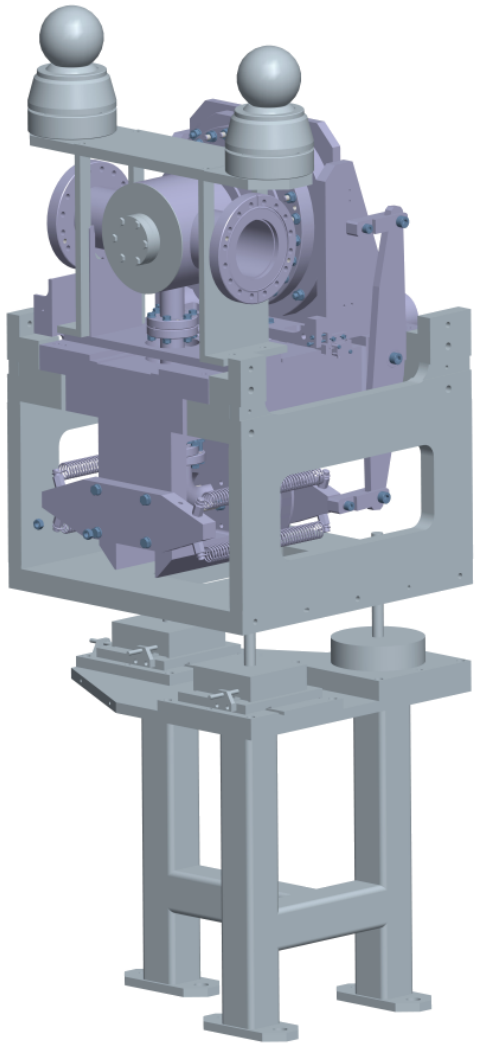
Introduction





- Many interesting physics processes result in colliding protons not being destroyed.
- In order to analyse their properties it is desirable to directly measure scattered protons.
- Due to properties of LHC magnetic field, scattered protons are travelling almost with the main beam, diverged from its trajectory only by few milimeters.
- In order to measure them at IP1 (ATLAS) and IP5 (CMS/TOTEM) dedicated devices, so-called Roman pots are installed.
- Roman pots operate during special (low pile-up) and standard (high pile-up) LHC fills.
  - They are moveable devices:
    - in "garage" position (few cm from the beam) when beams are not stable,
    - 2-4 mm from the beam when taking data.

Roman Pot Technology

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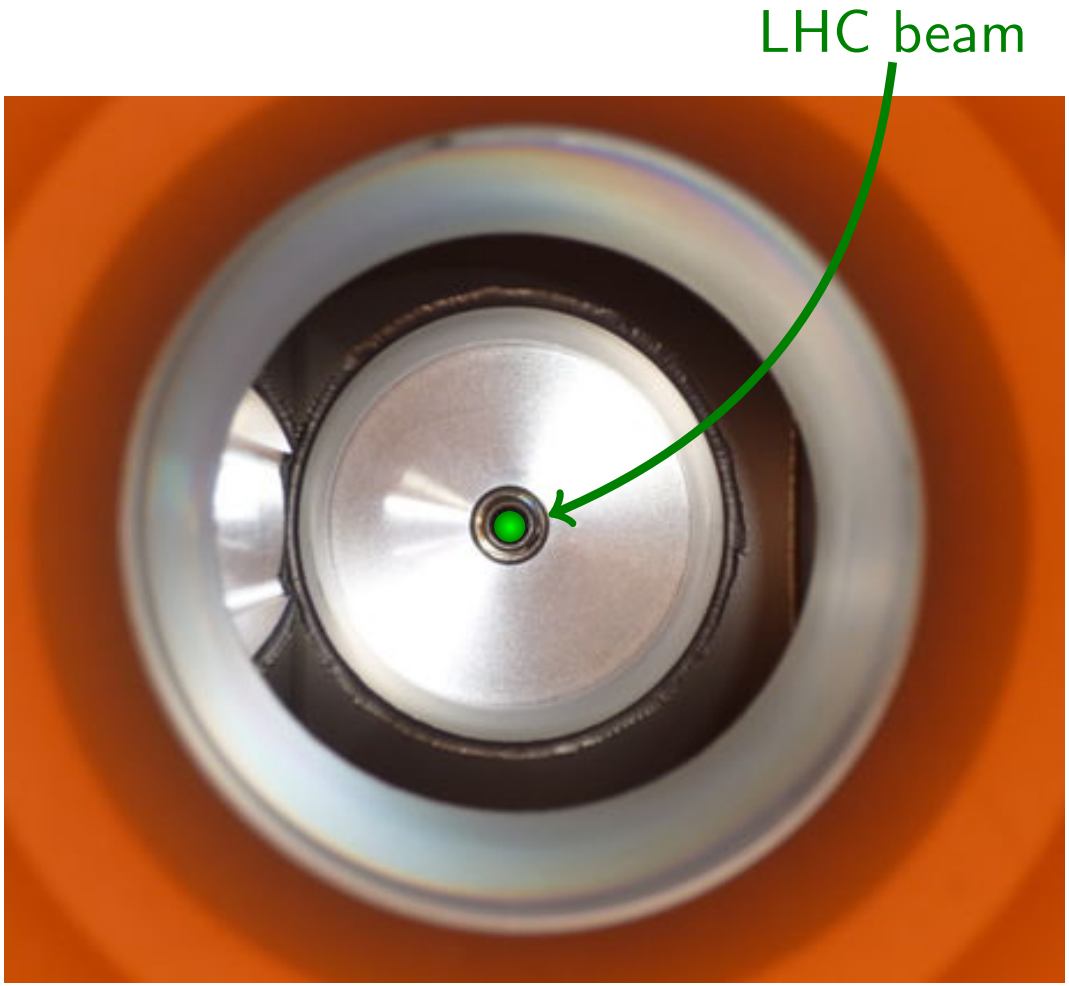

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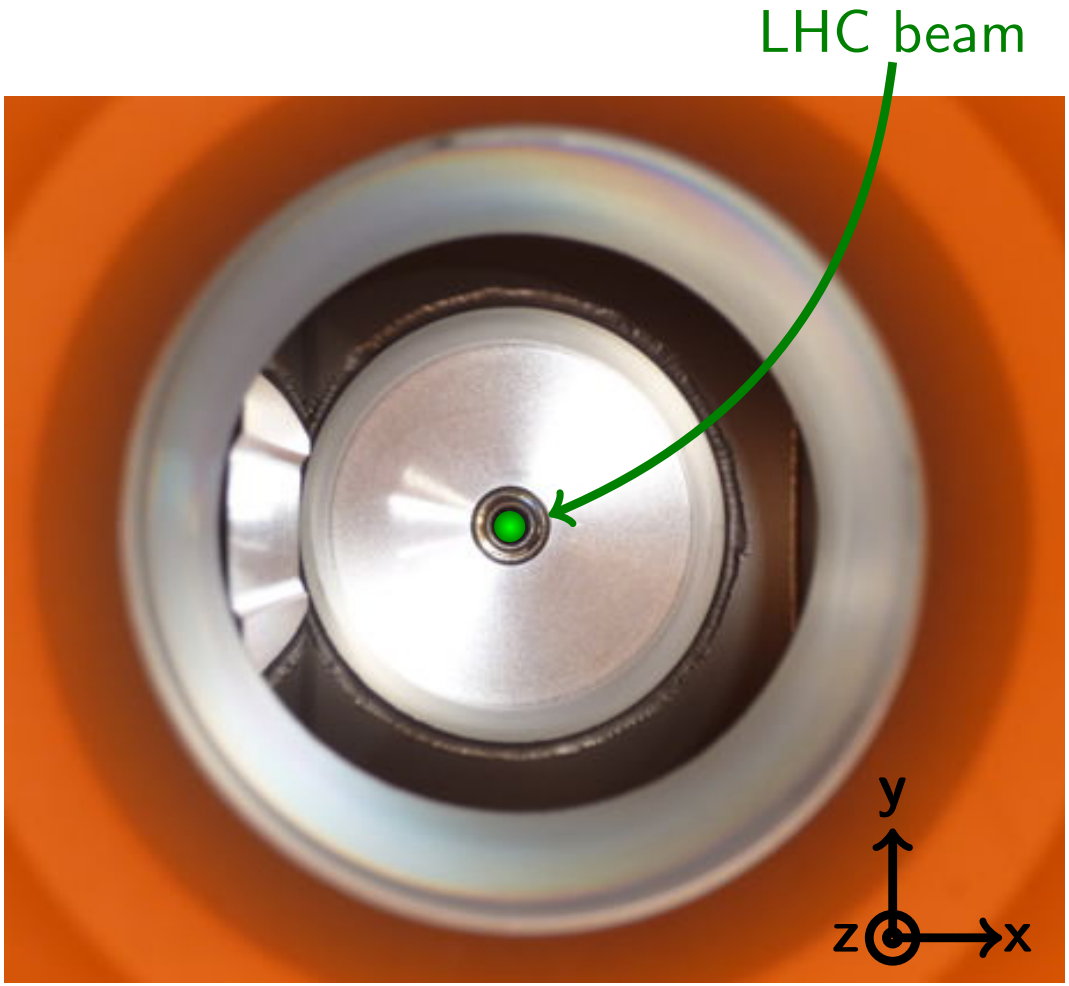

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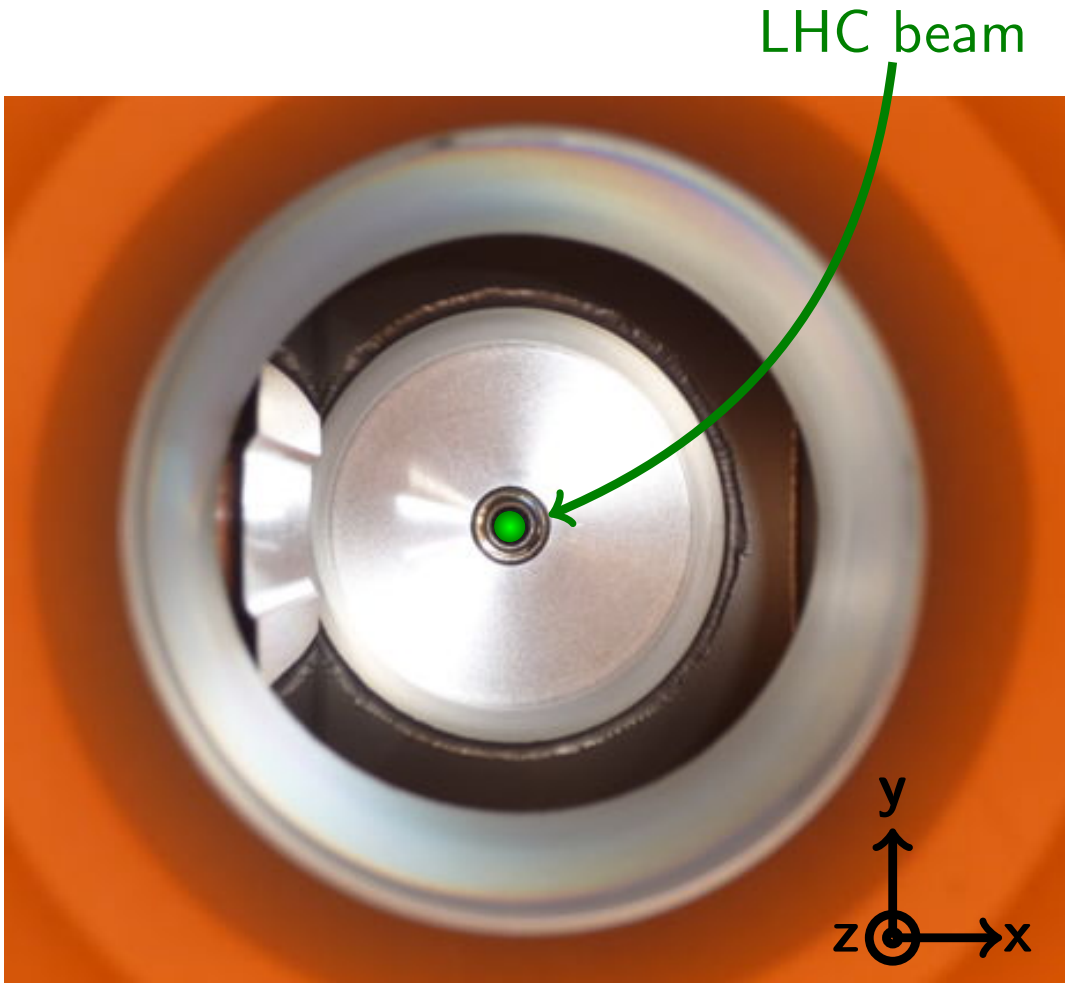

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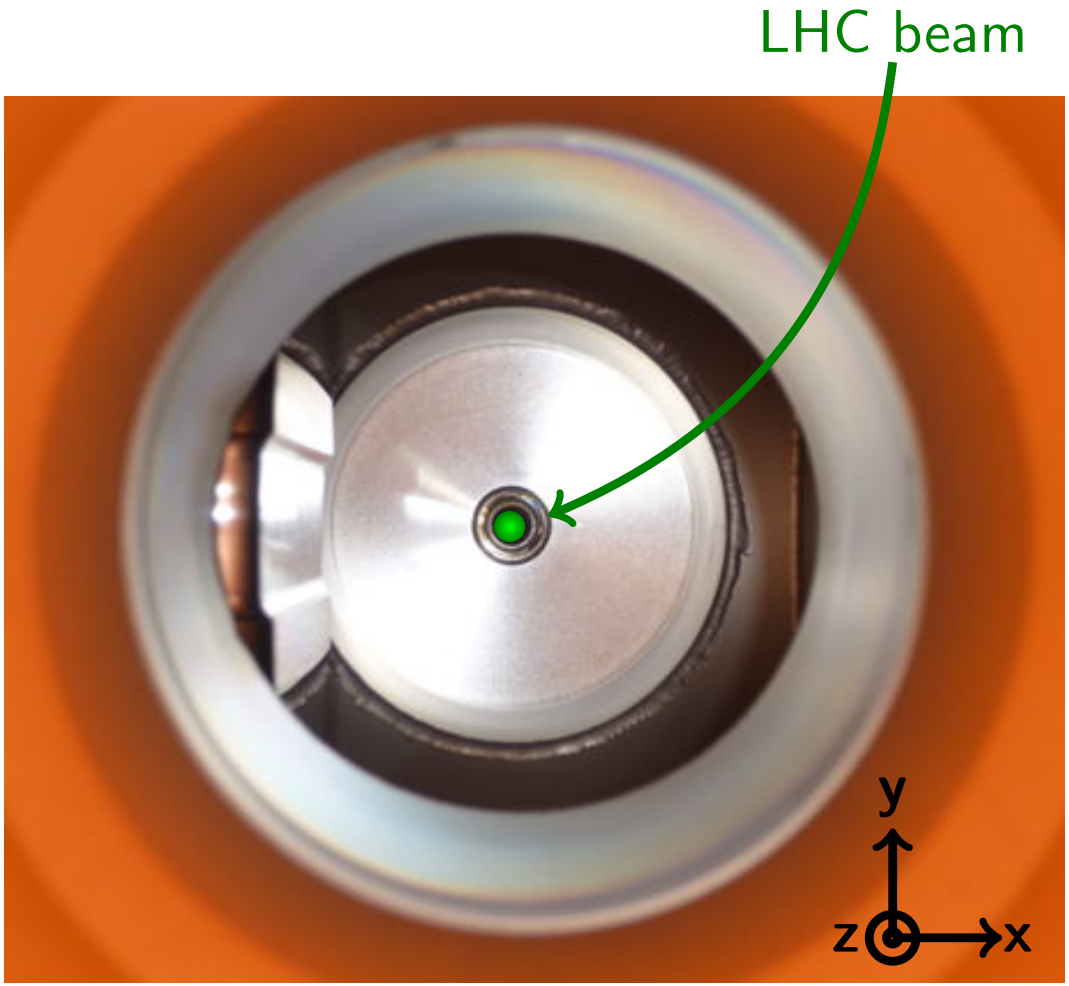

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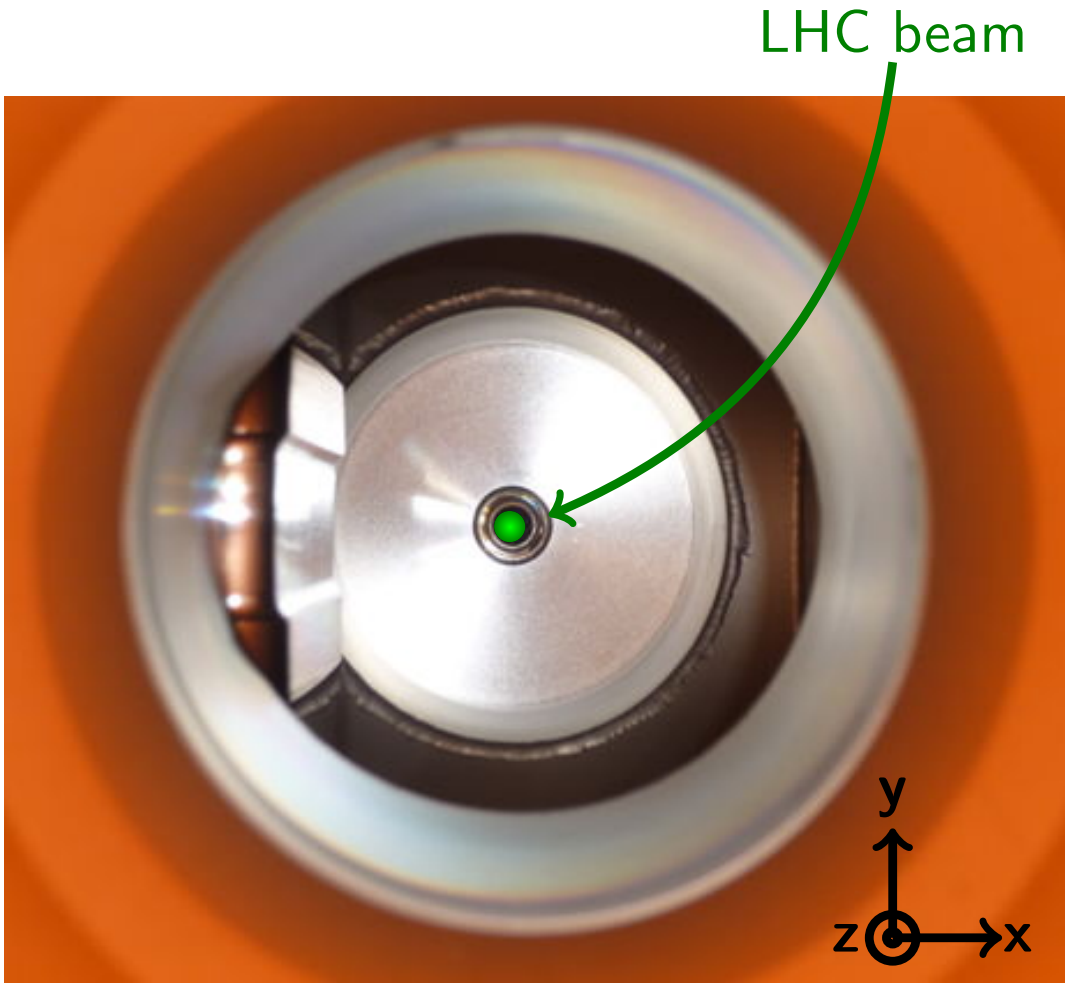

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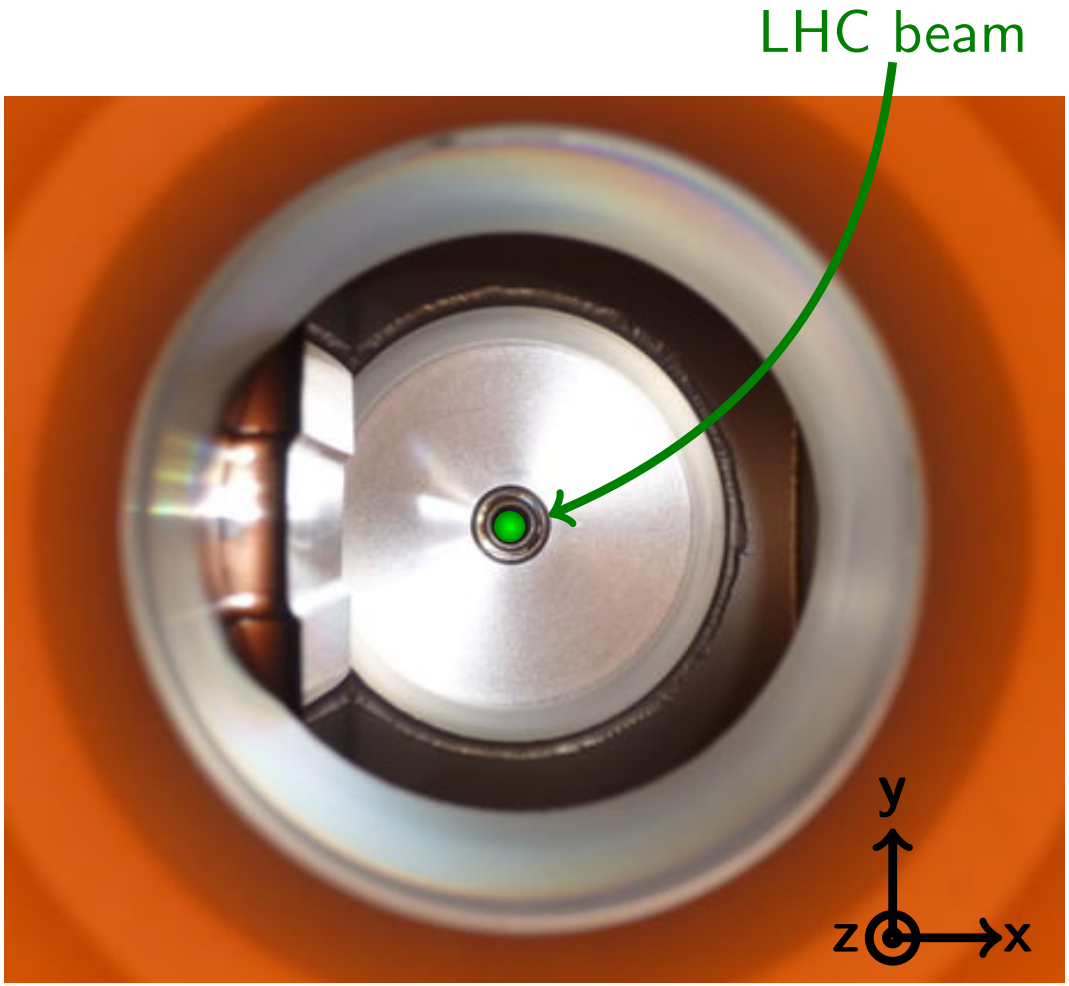

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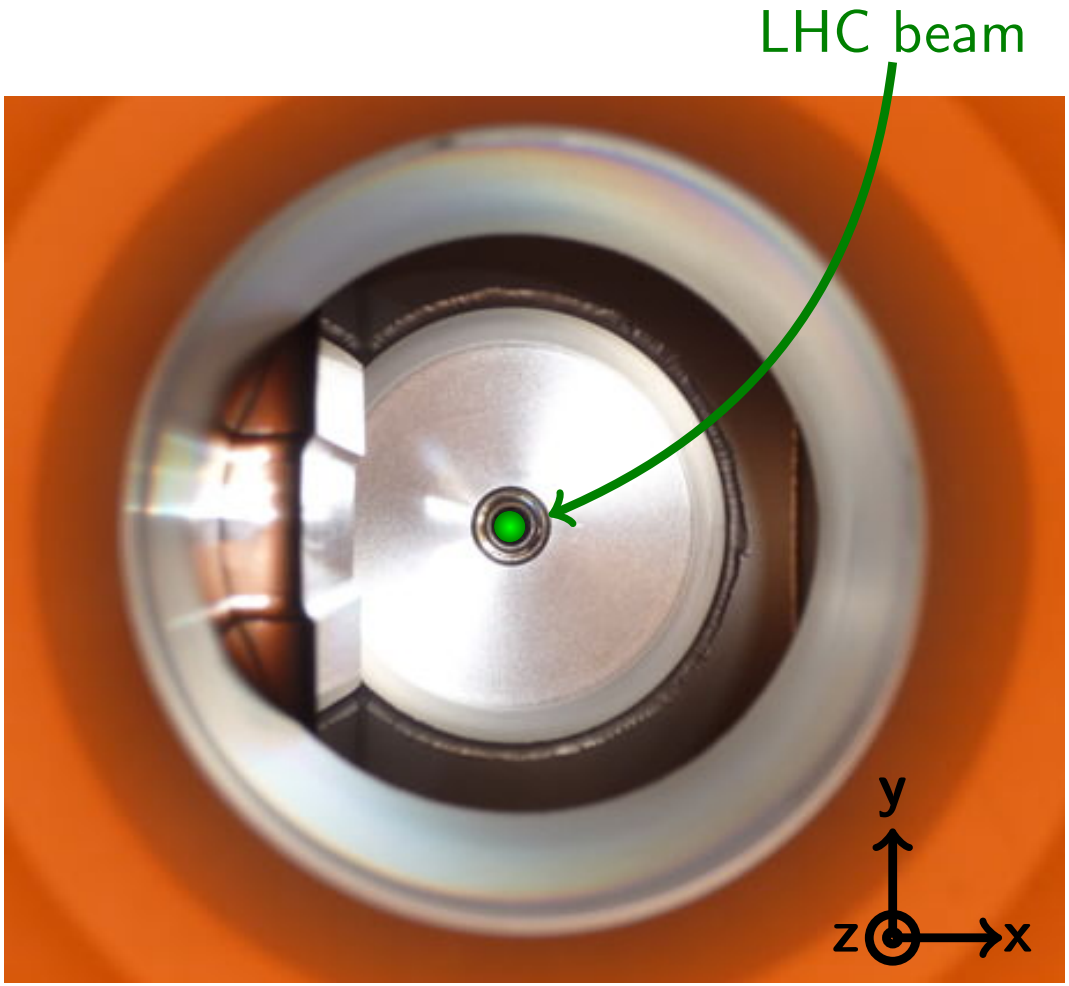

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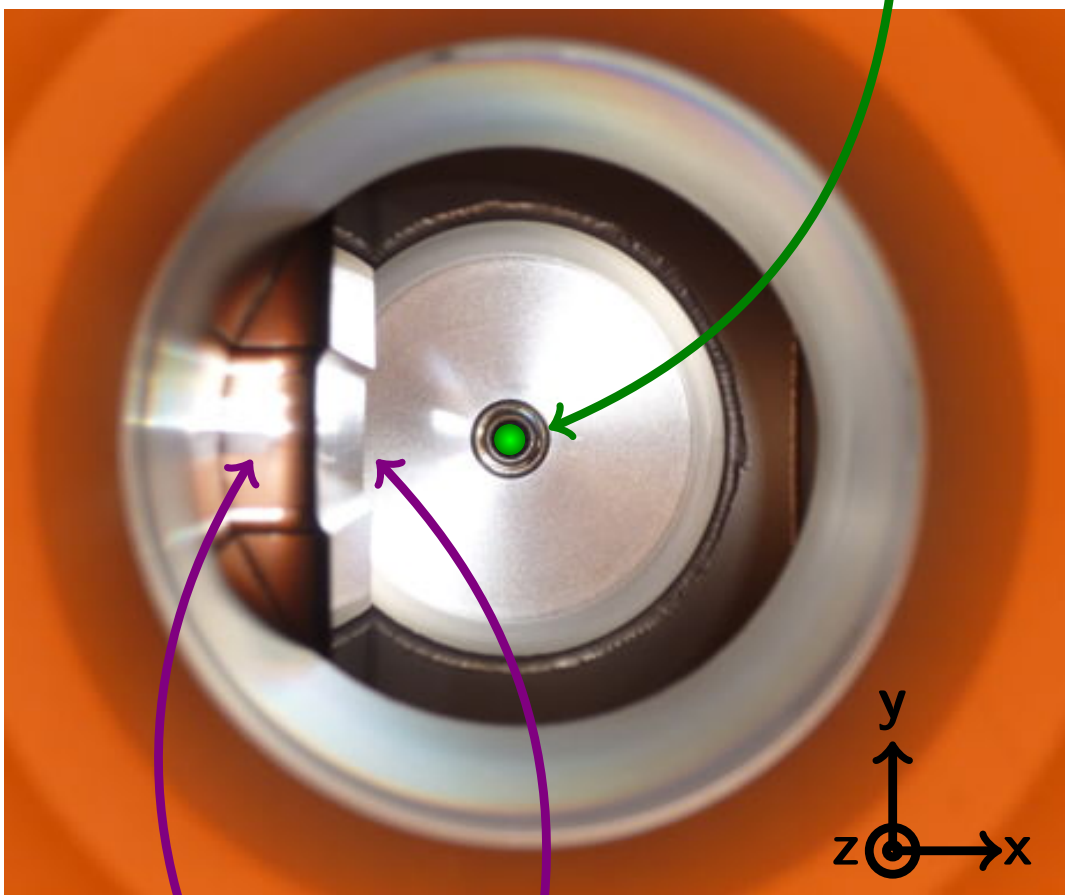
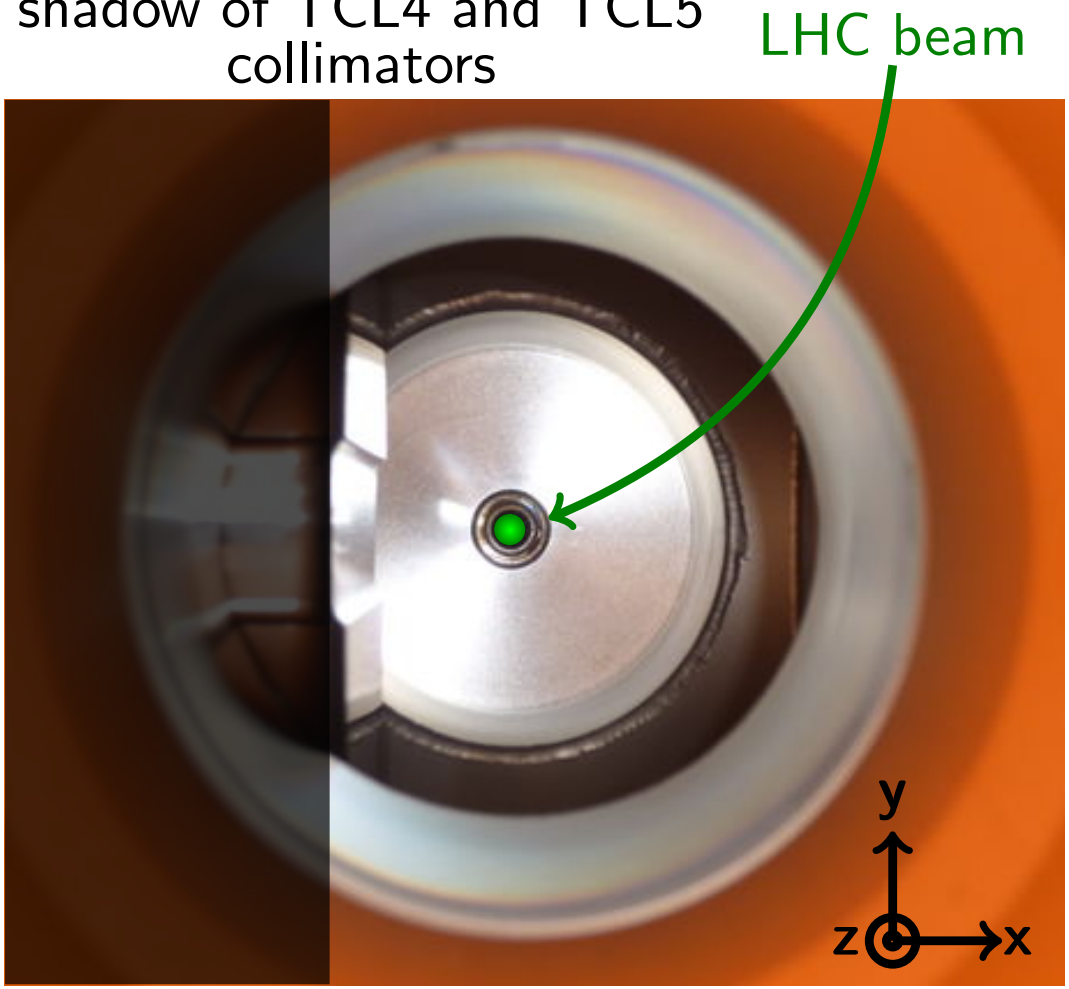
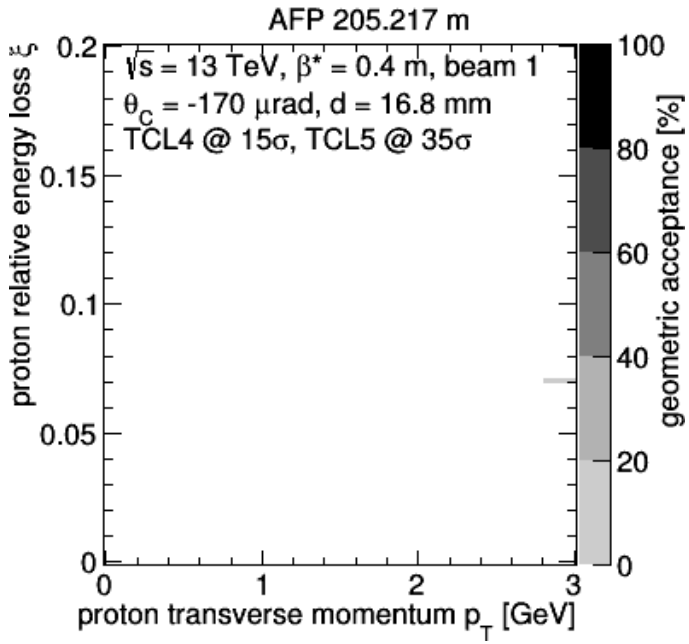


shadow of TCL4 and TCL5 collimators



thin window and floor (300 μm)

Geometric acceptance:



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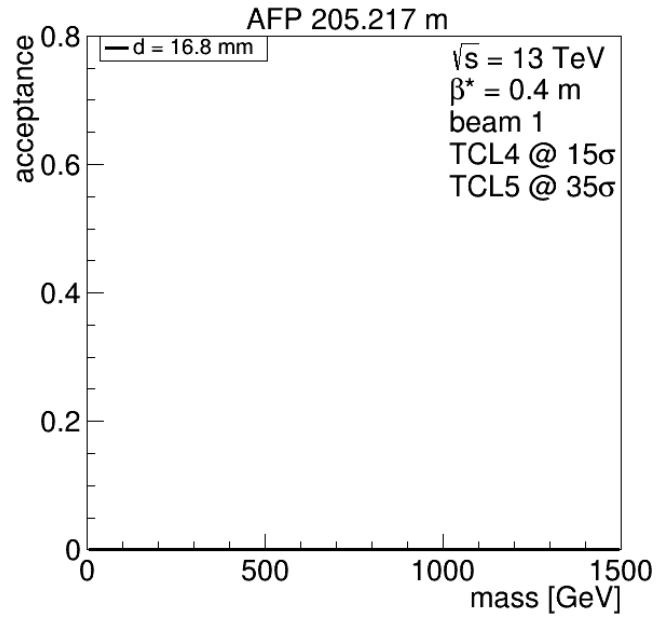

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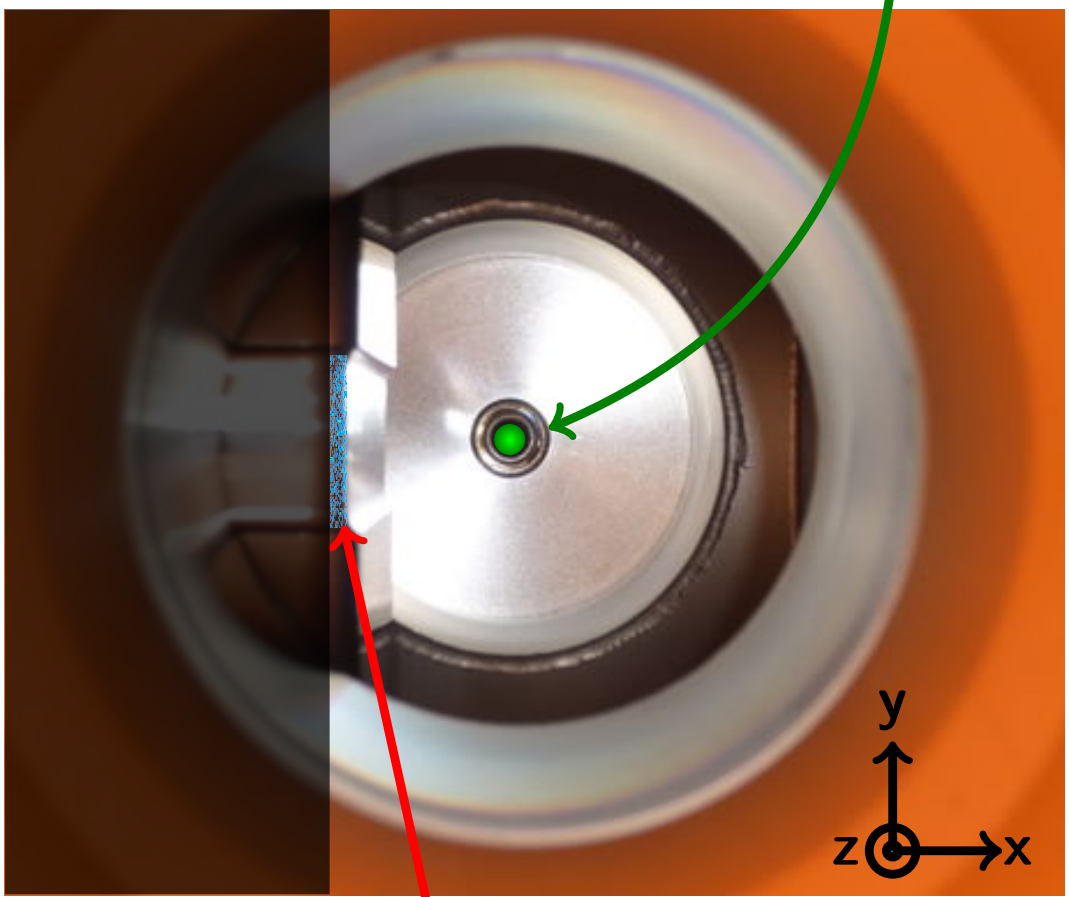
LHC beam



diffractive protons

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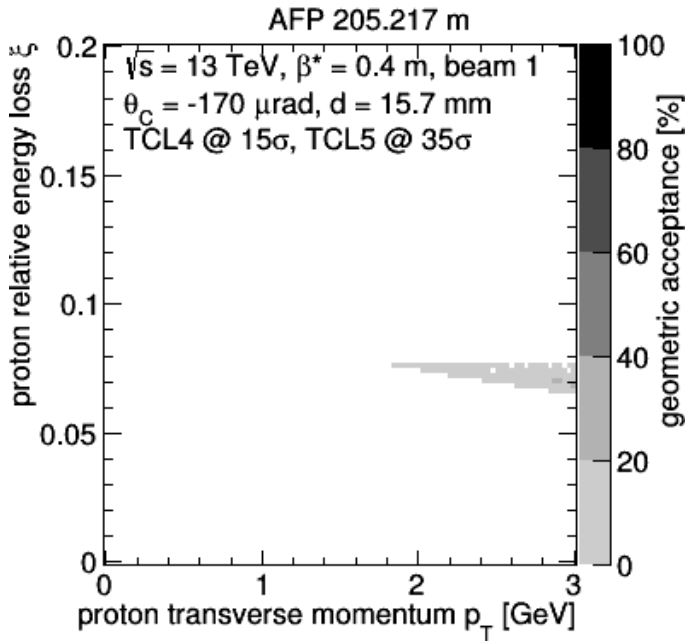

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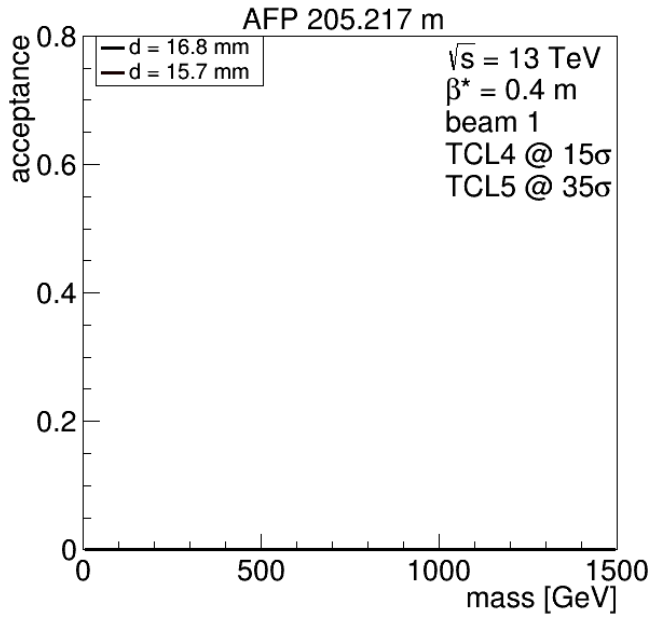

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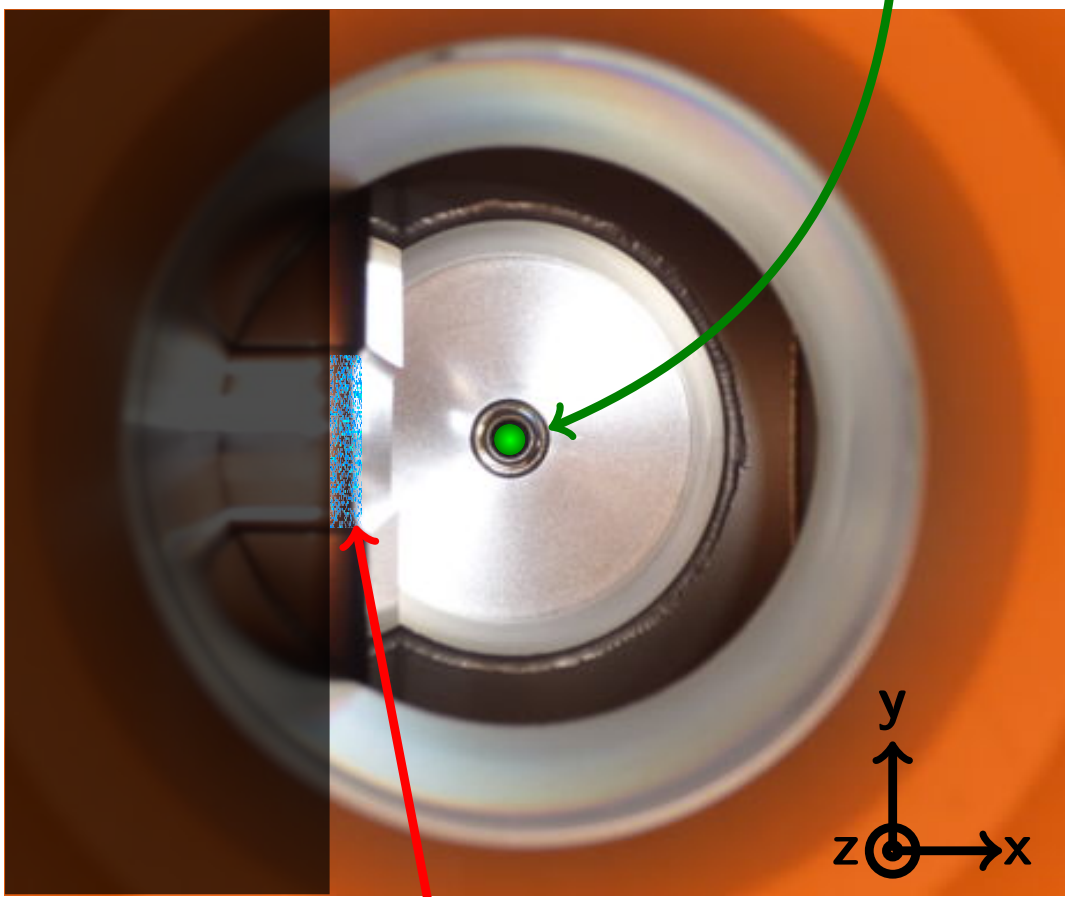

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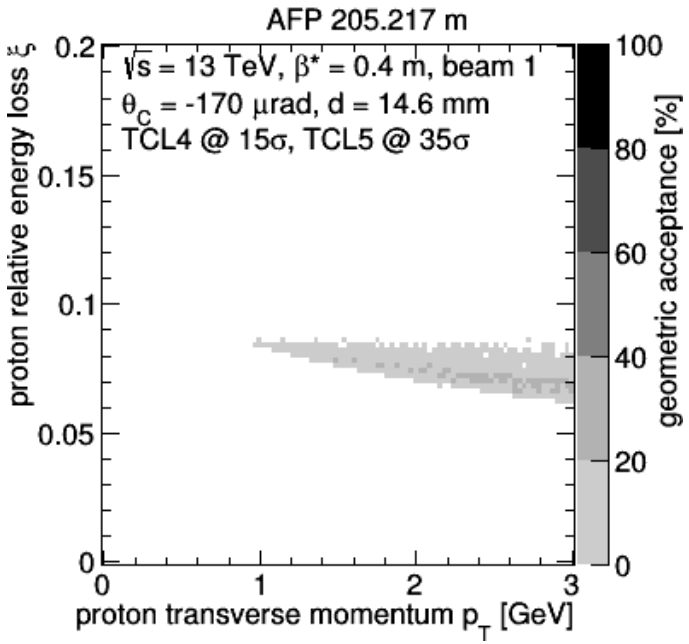

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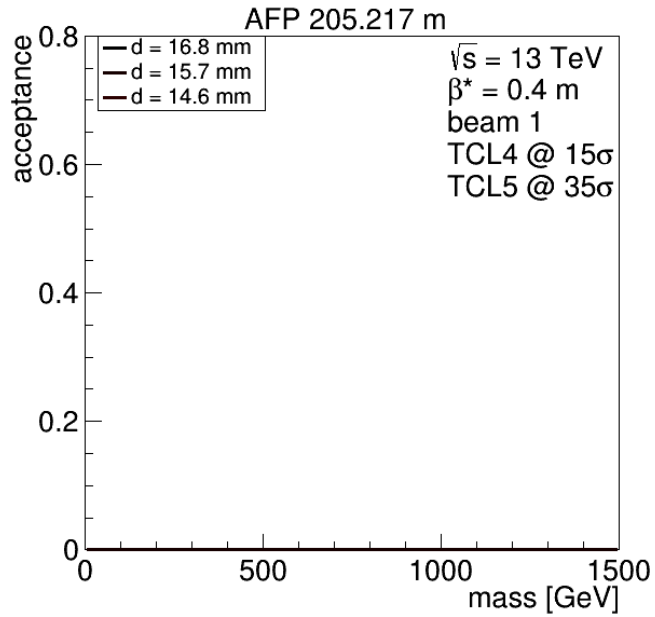

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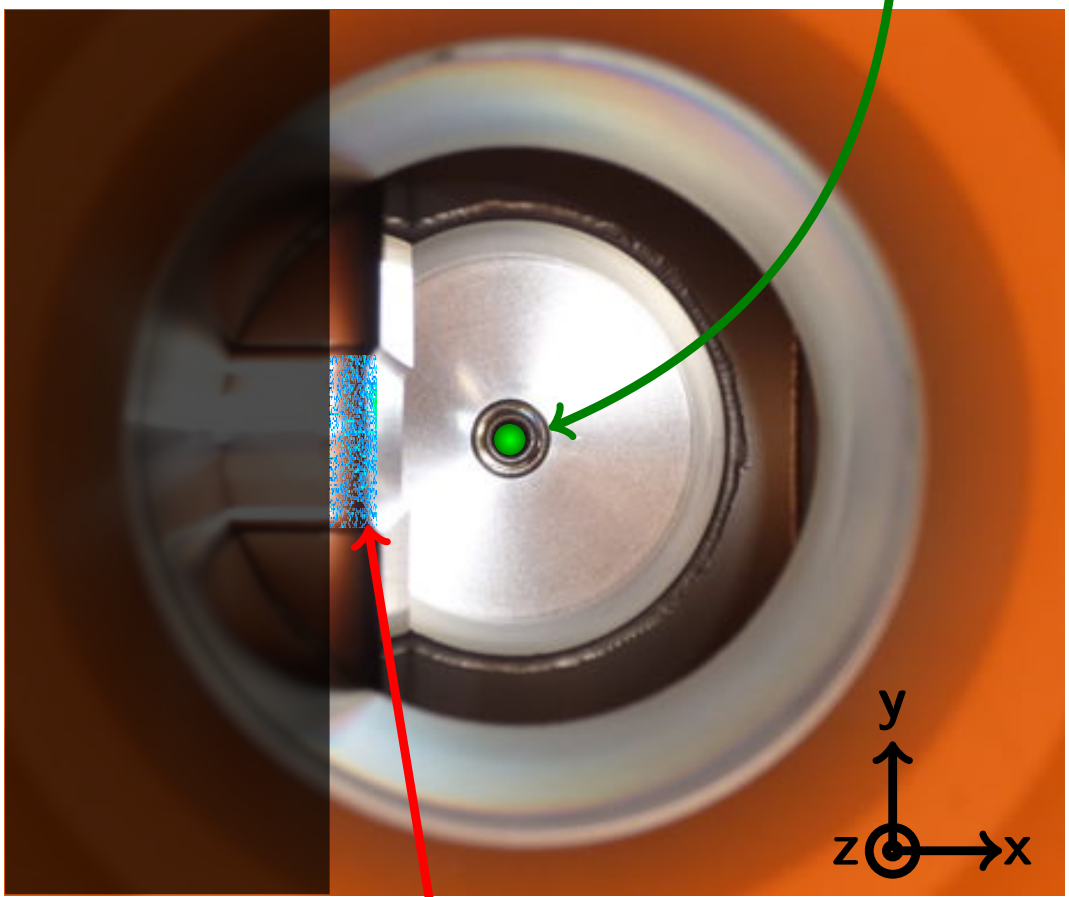

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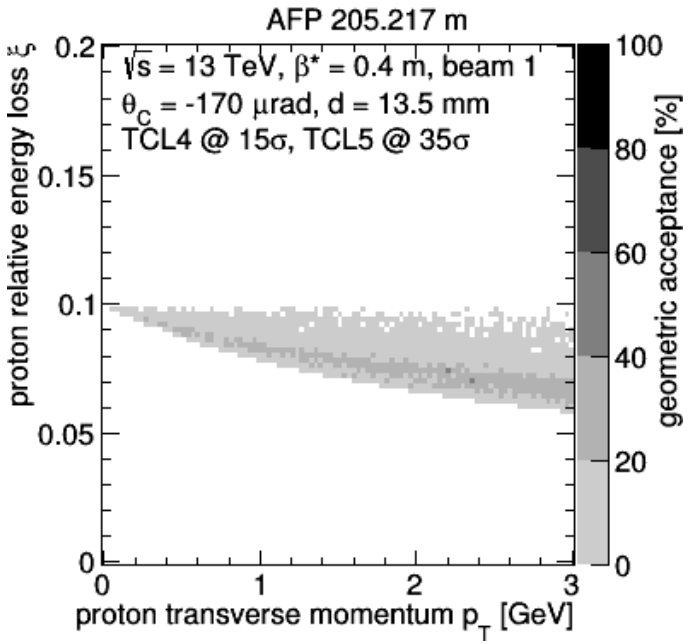

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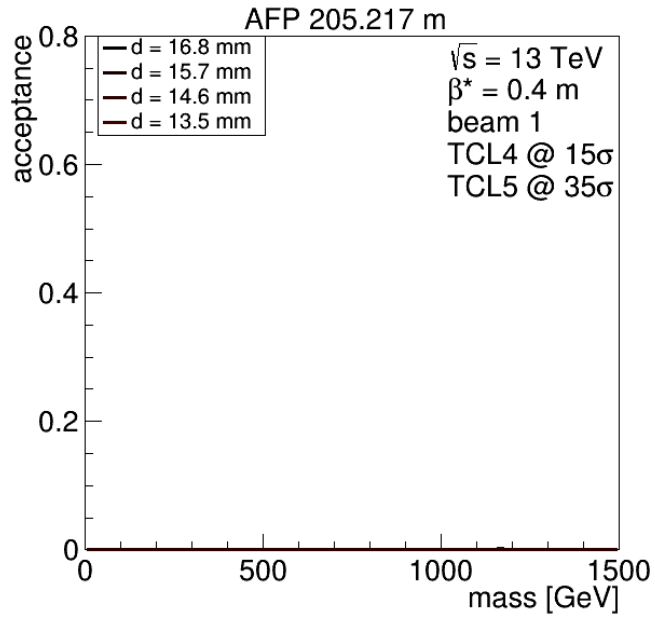

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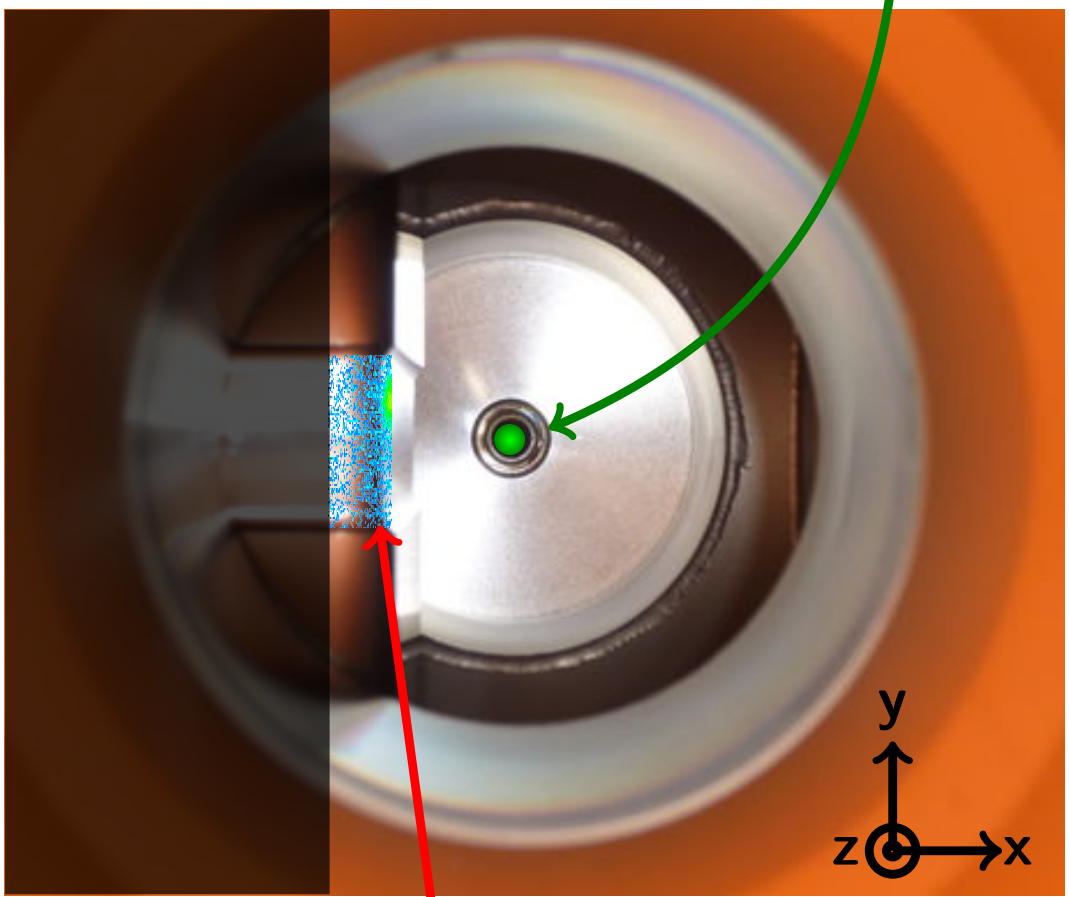

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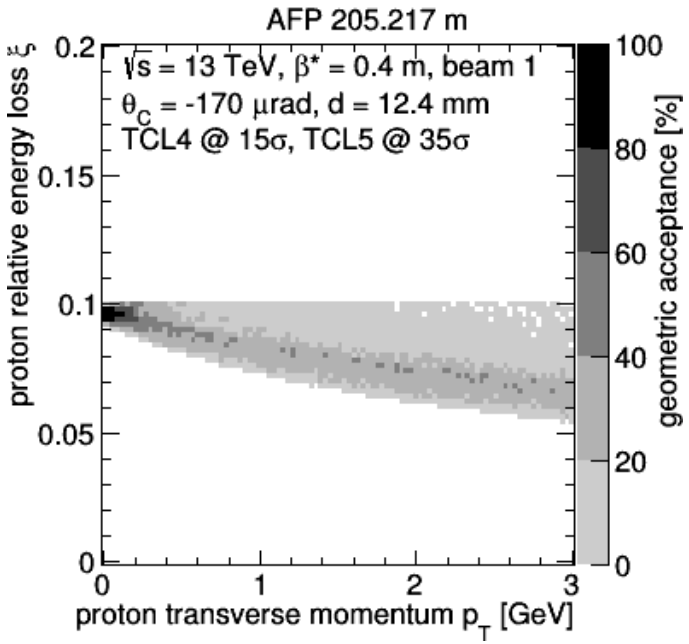

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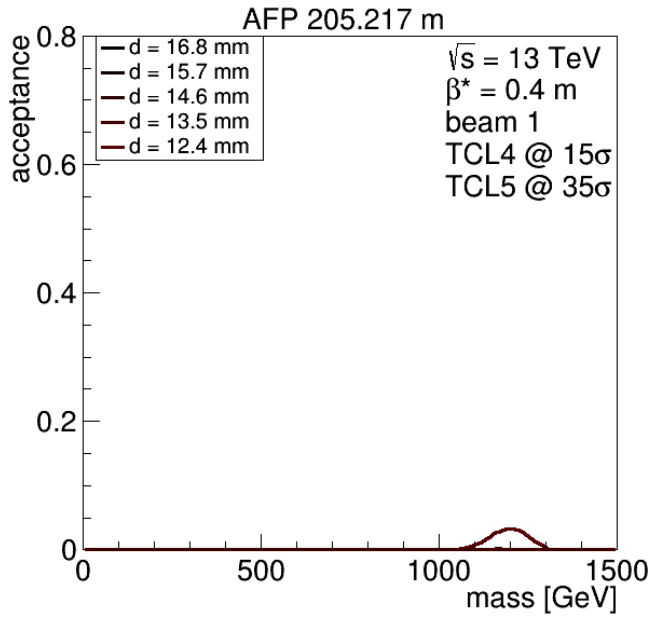

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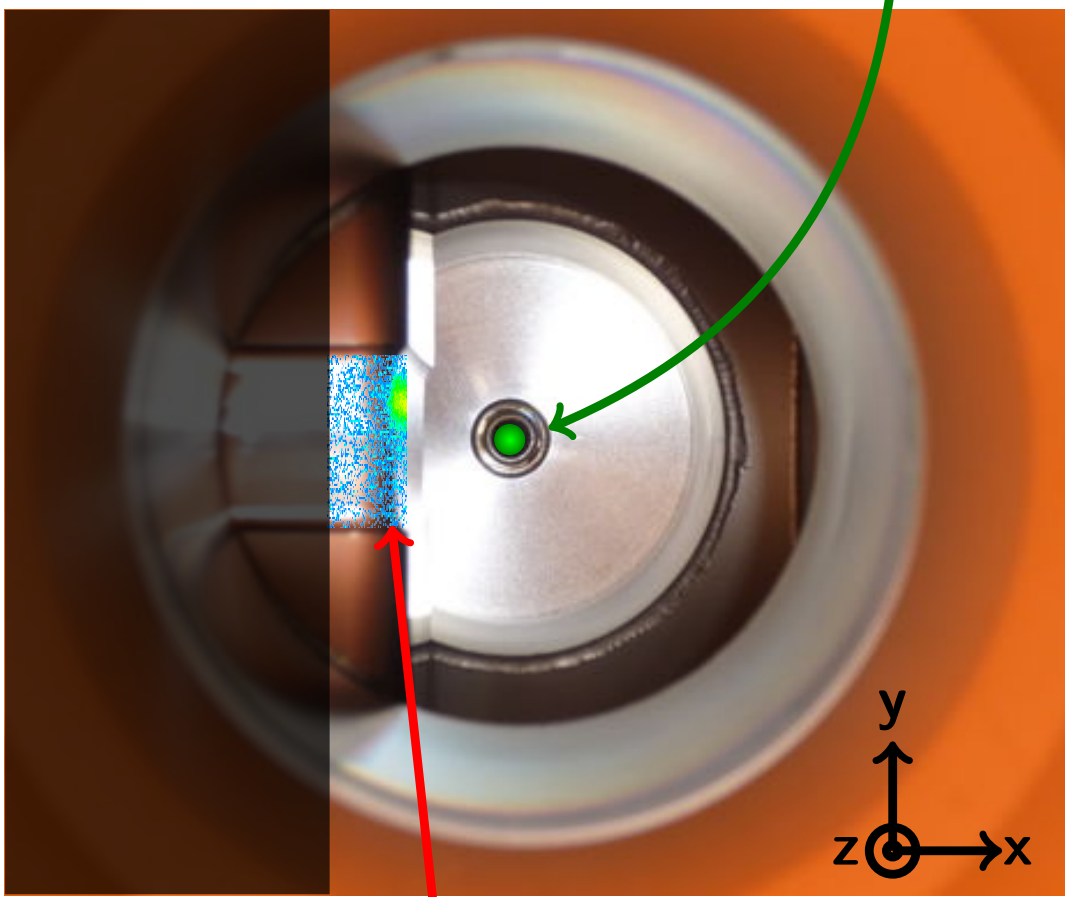

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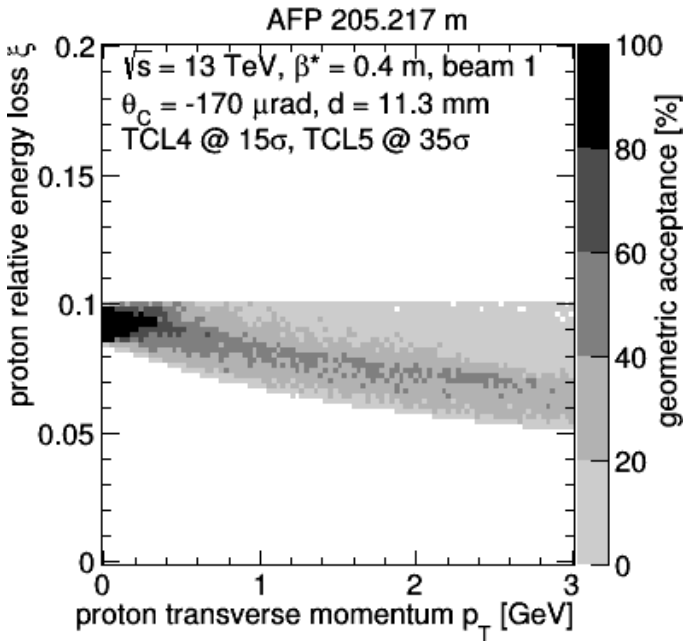

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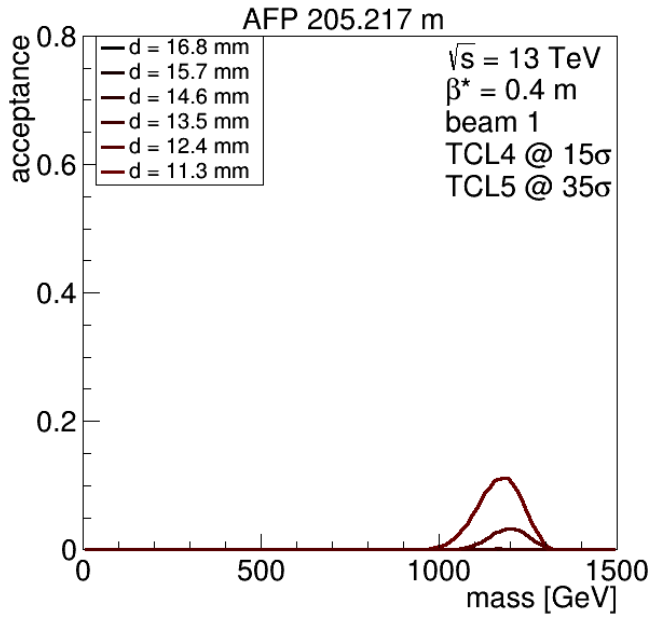

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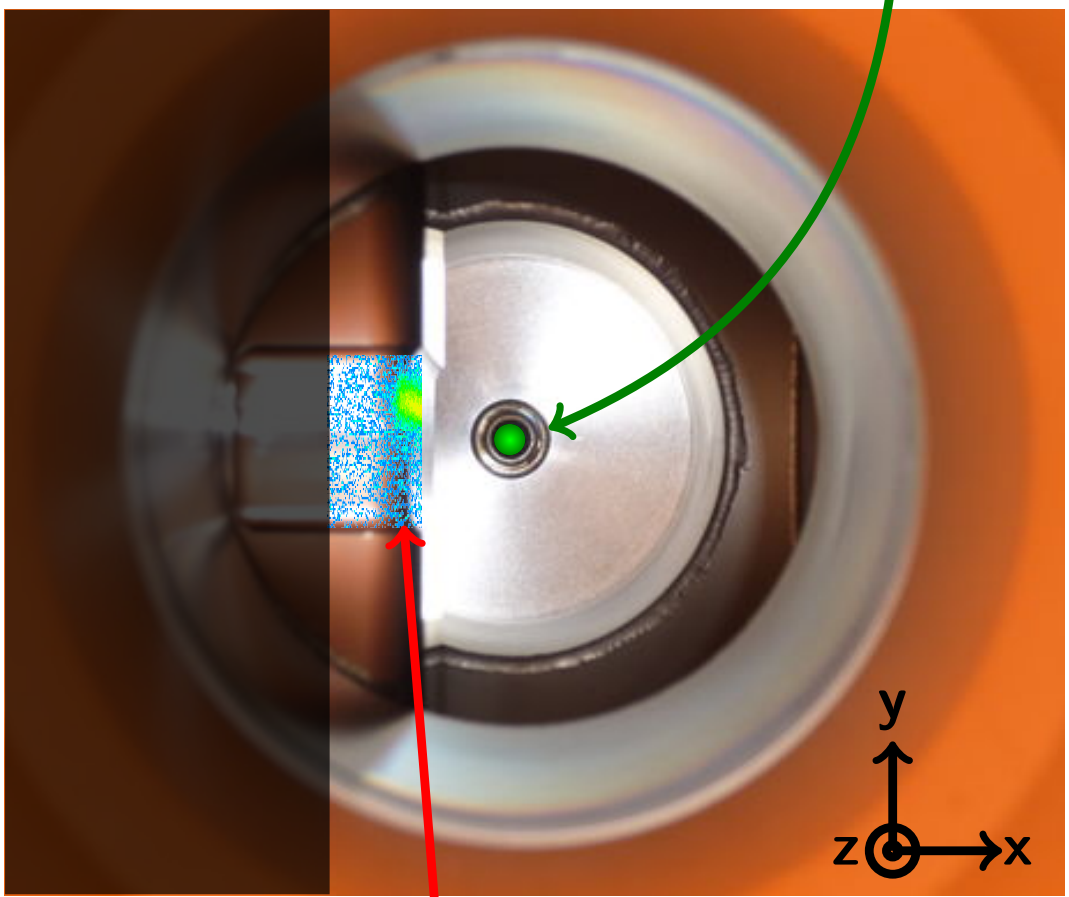

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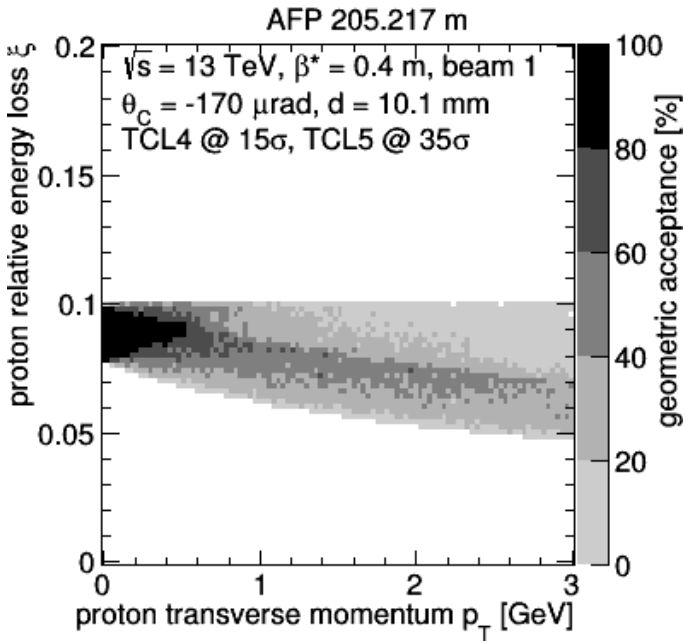

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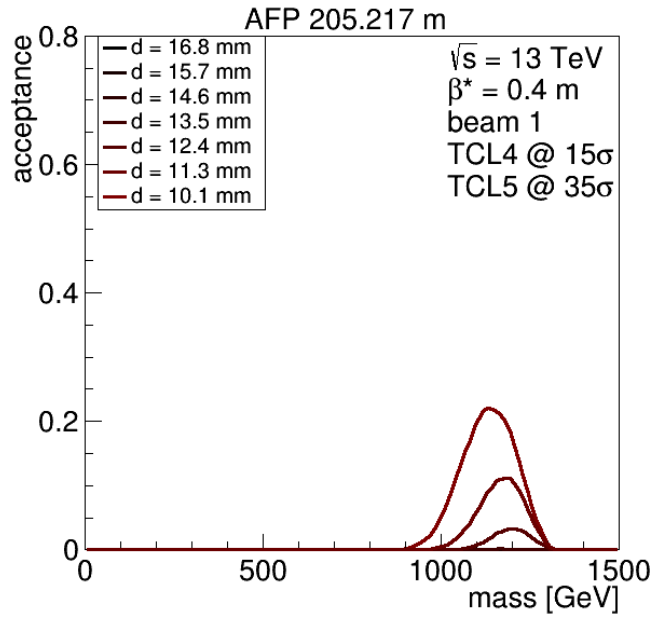

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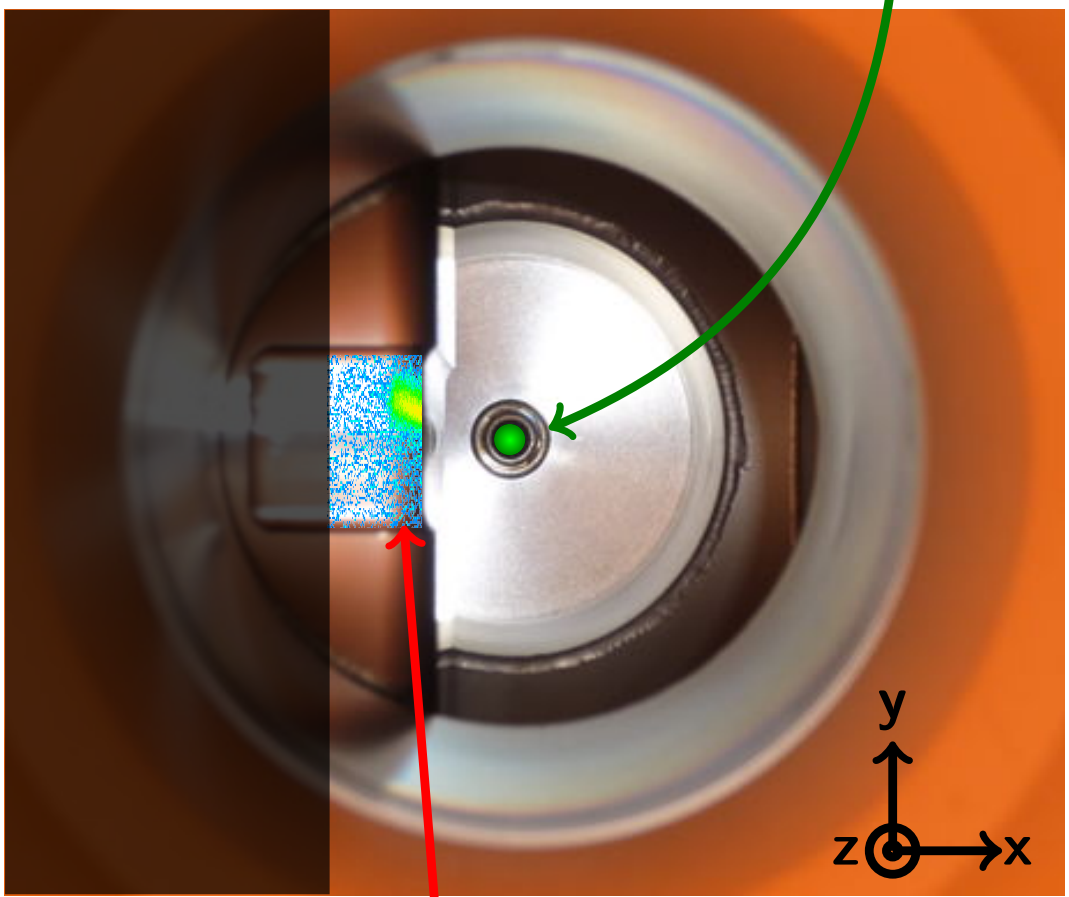

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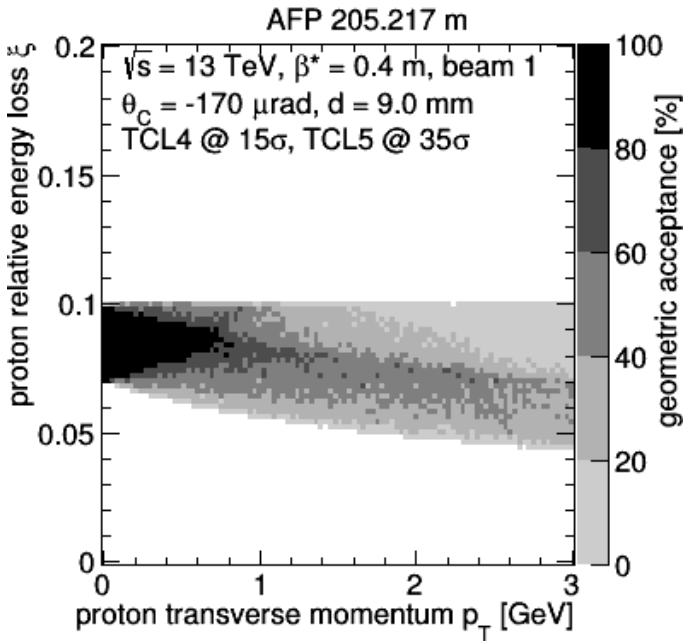

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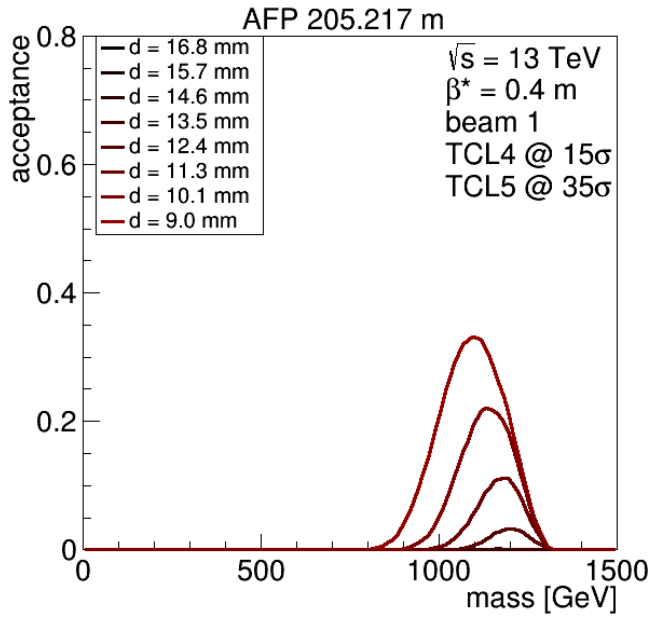

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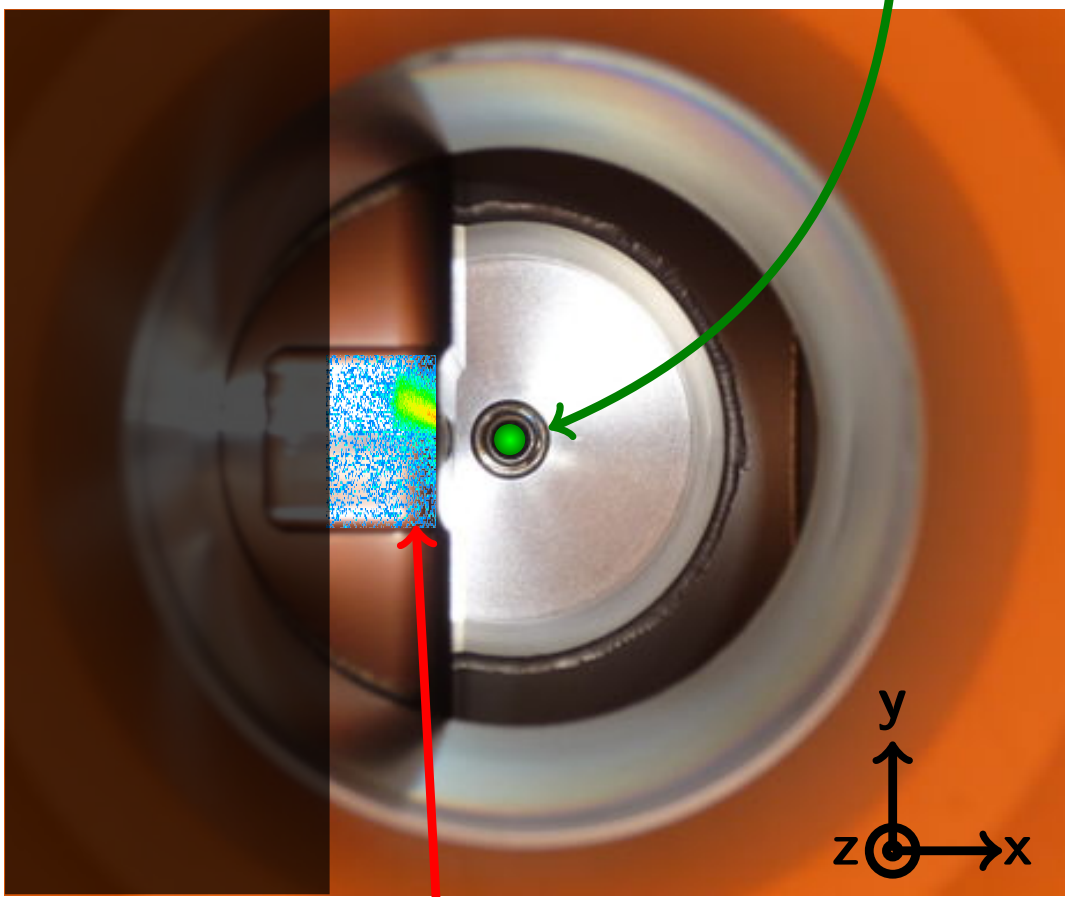

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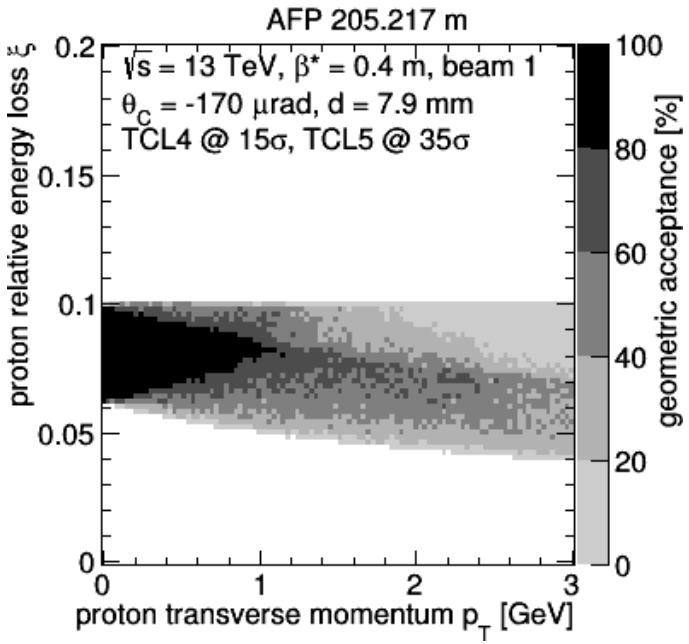

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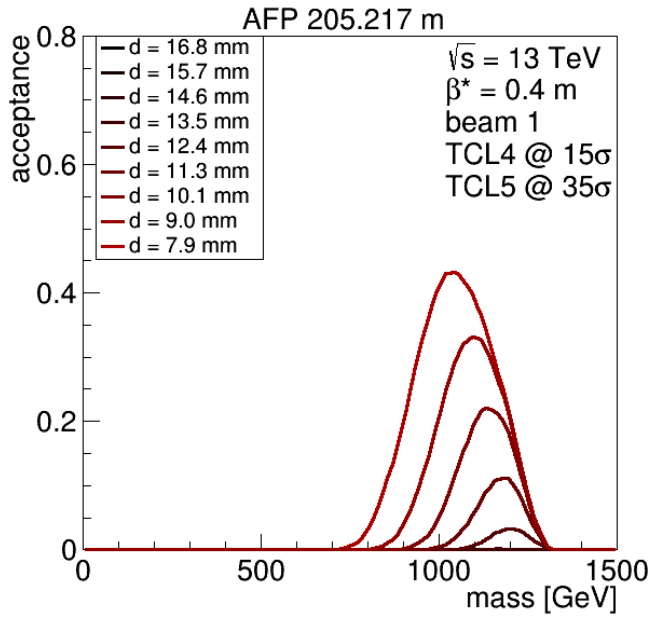

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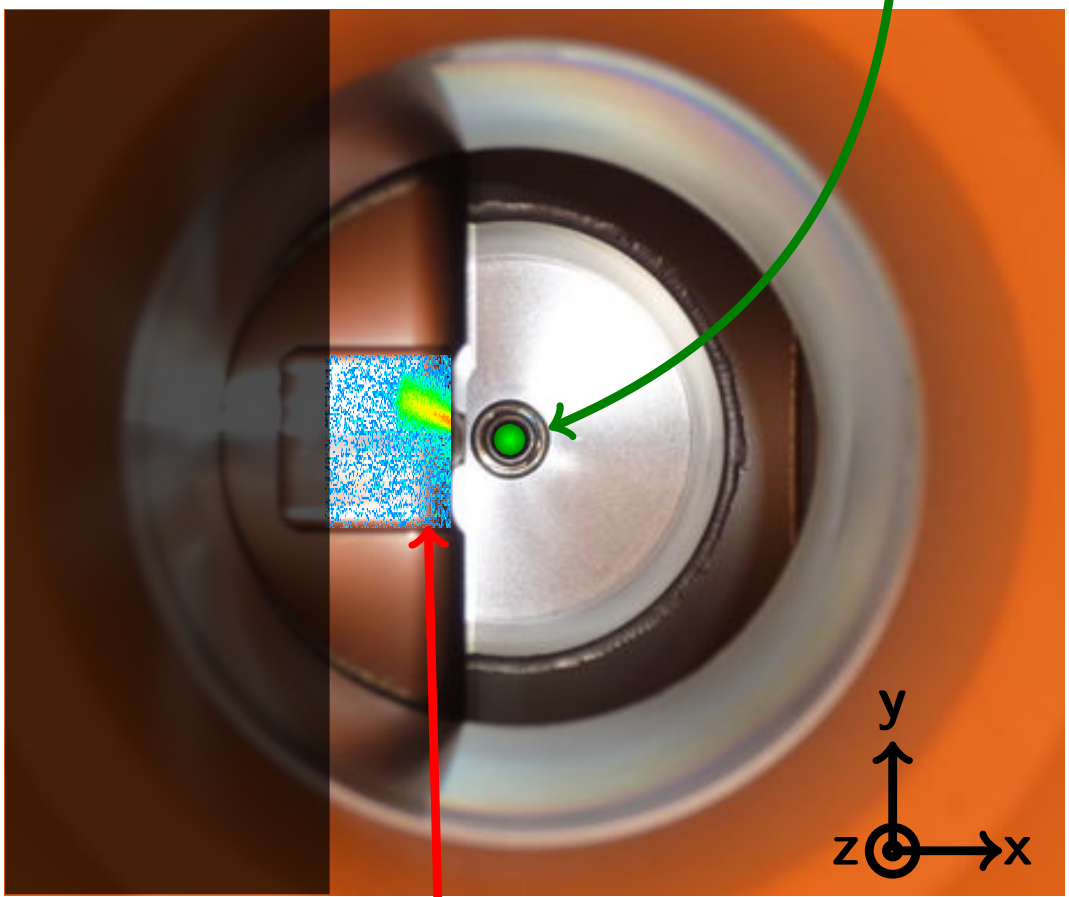

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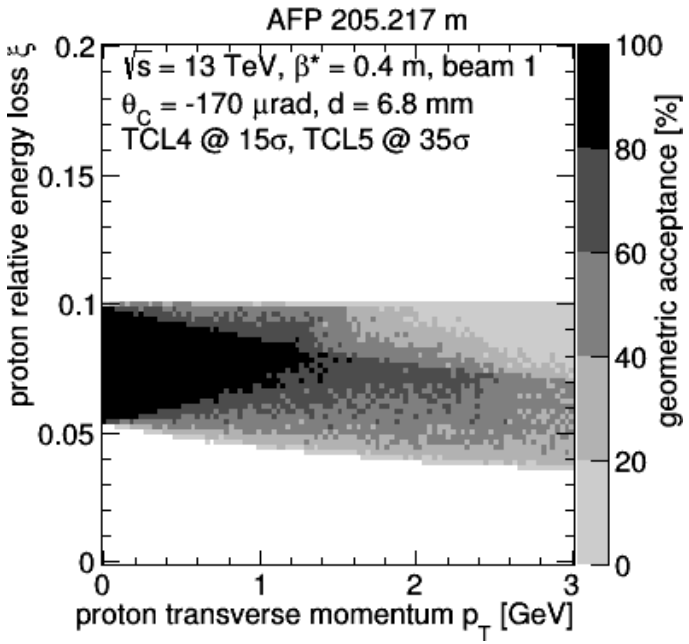

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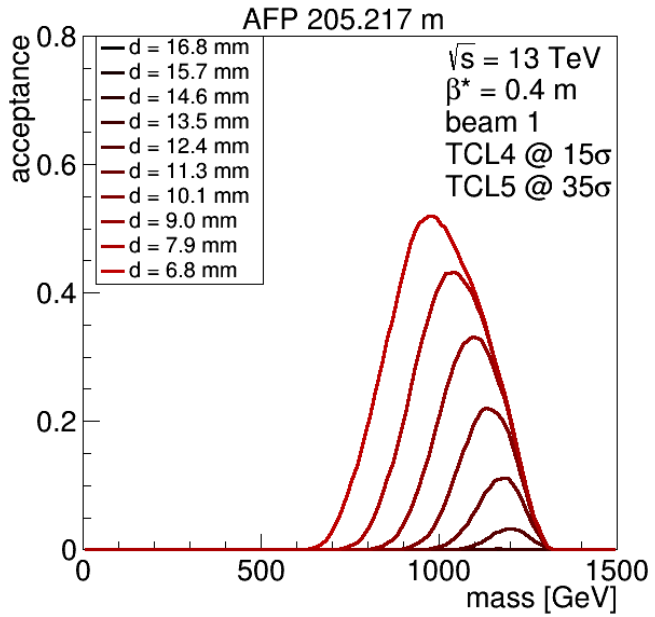

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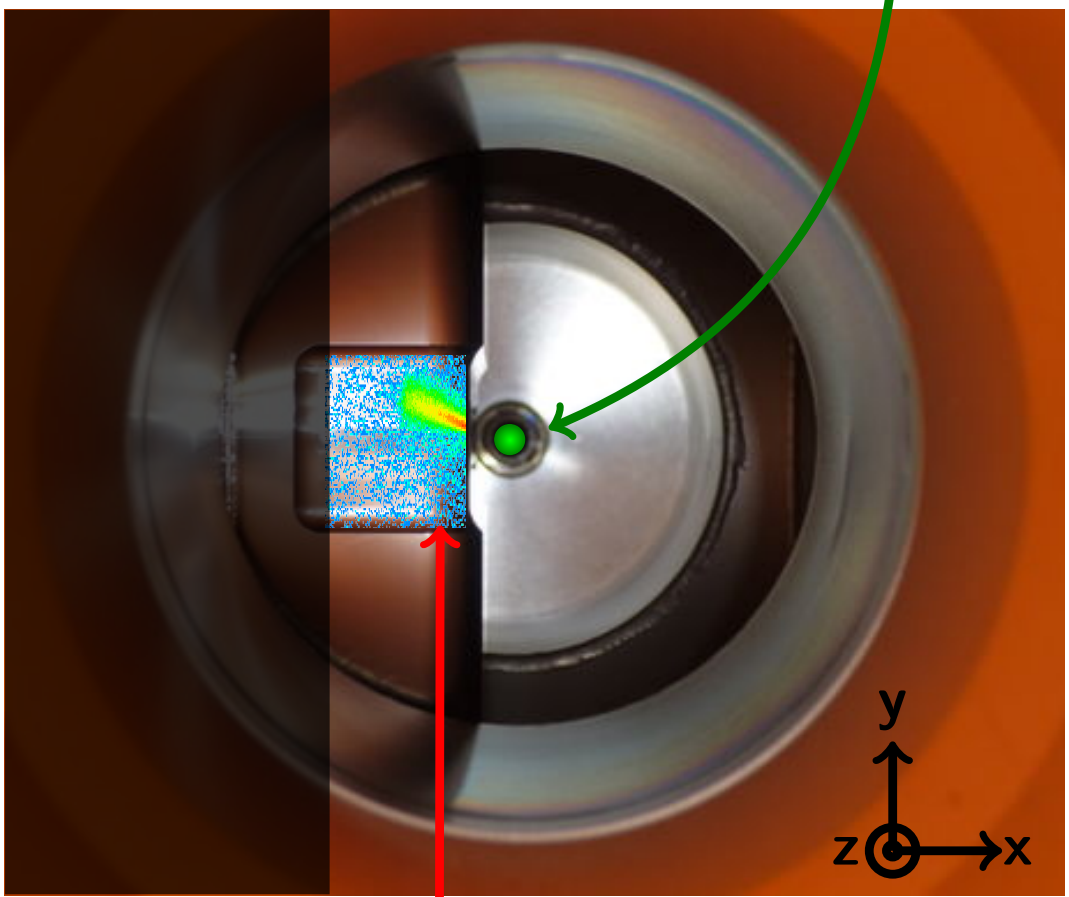

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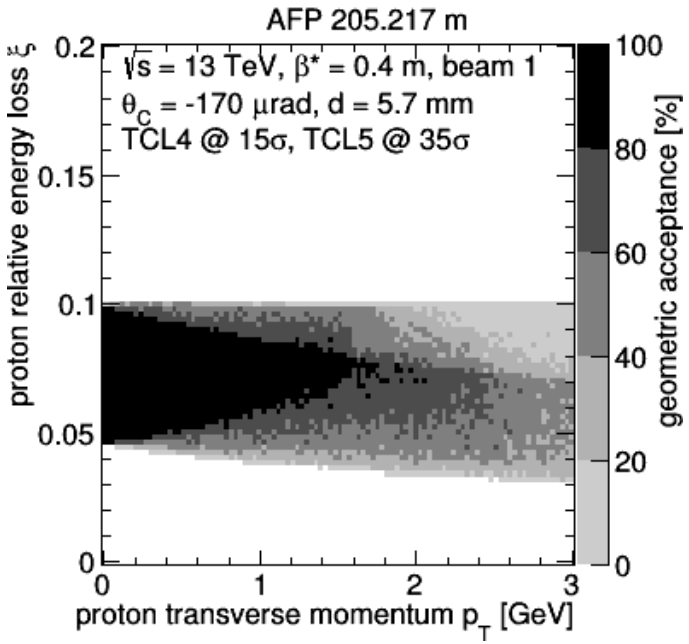

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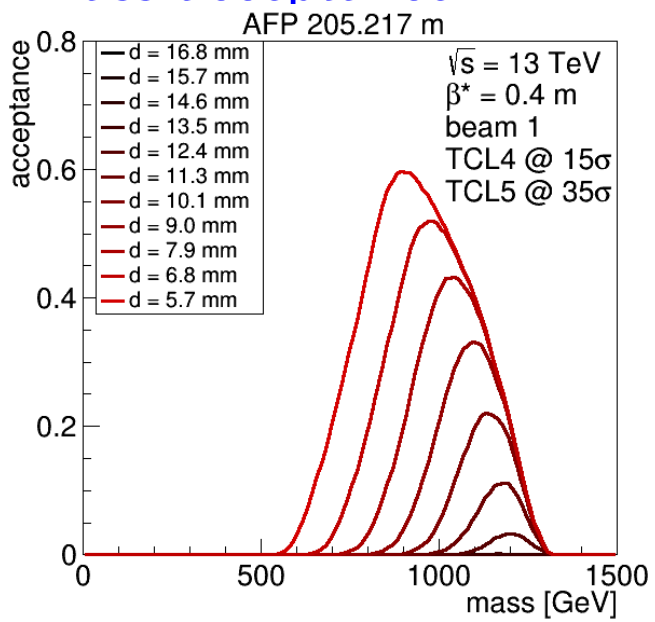

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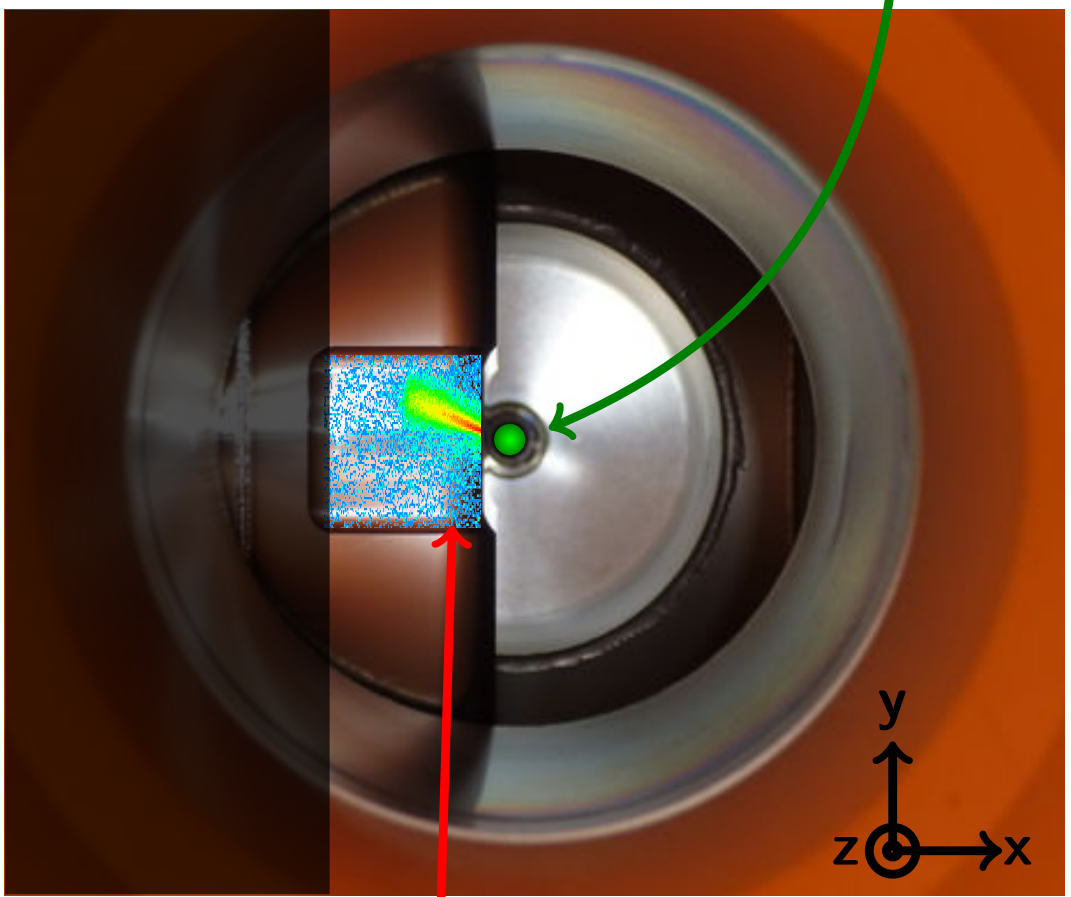

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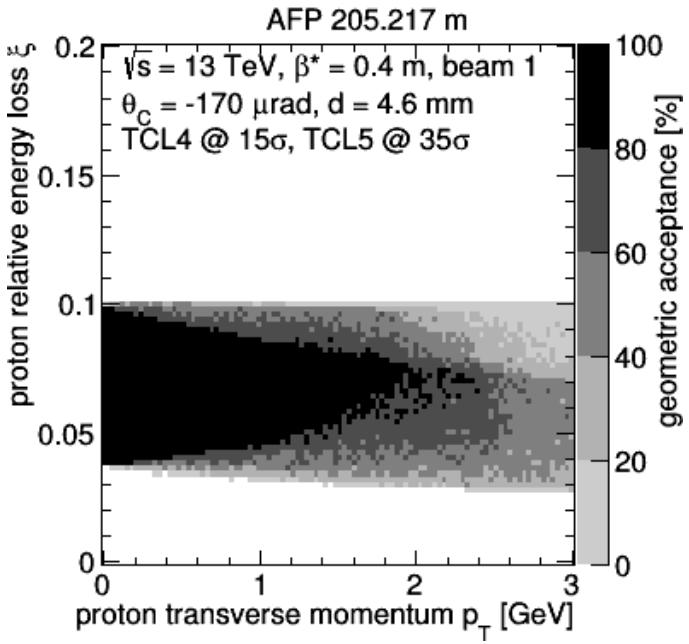

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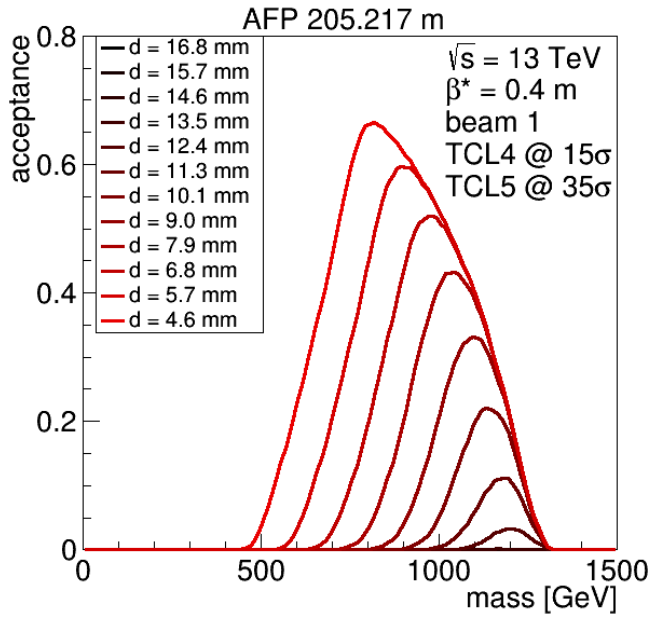

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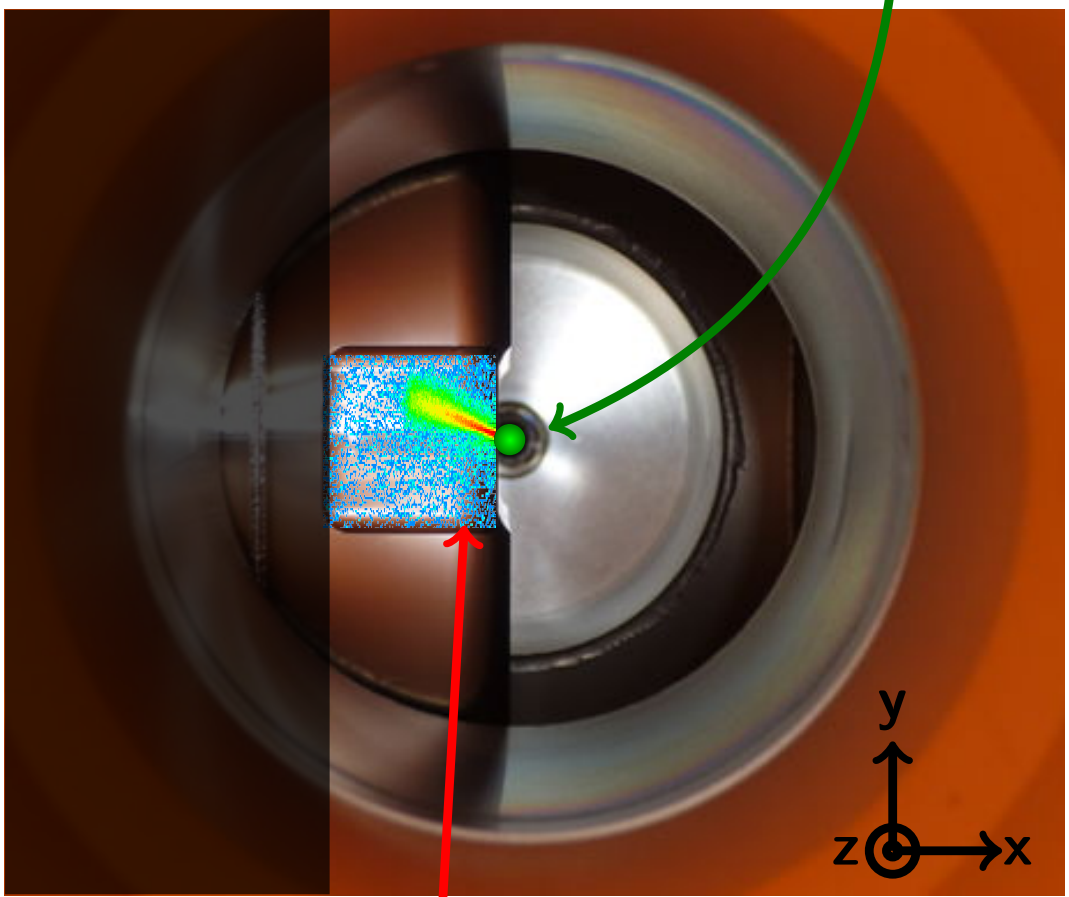

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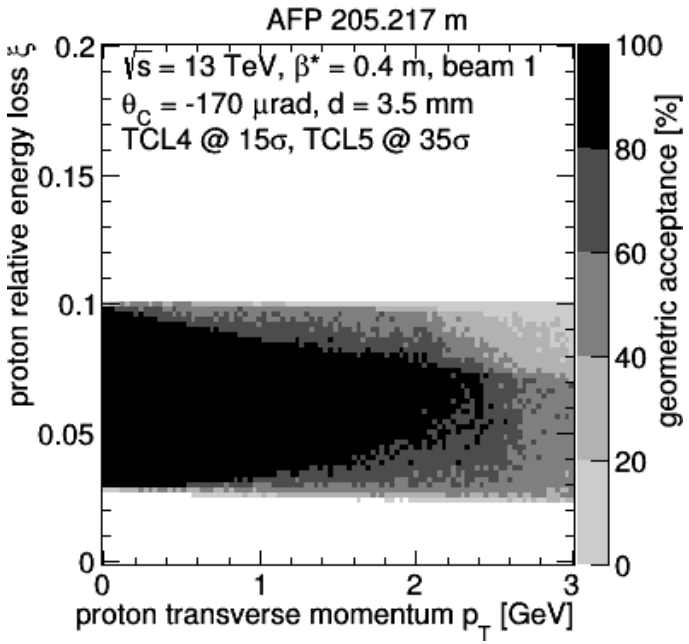

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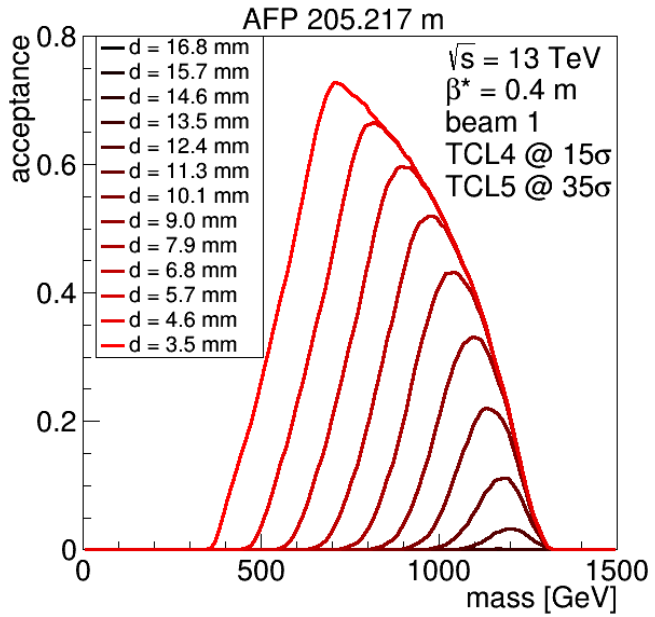
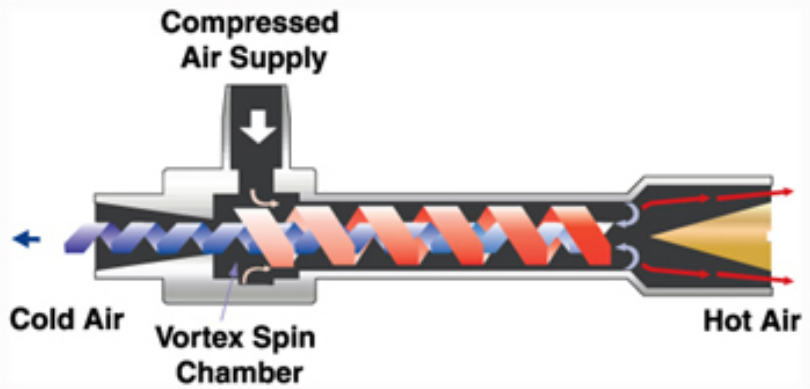
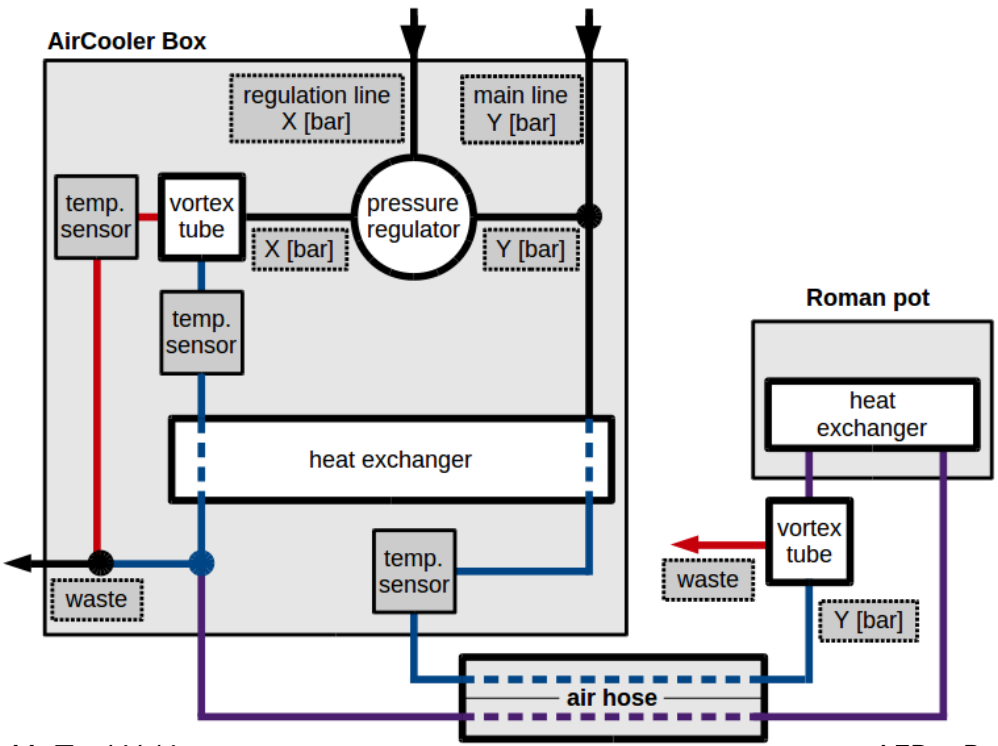
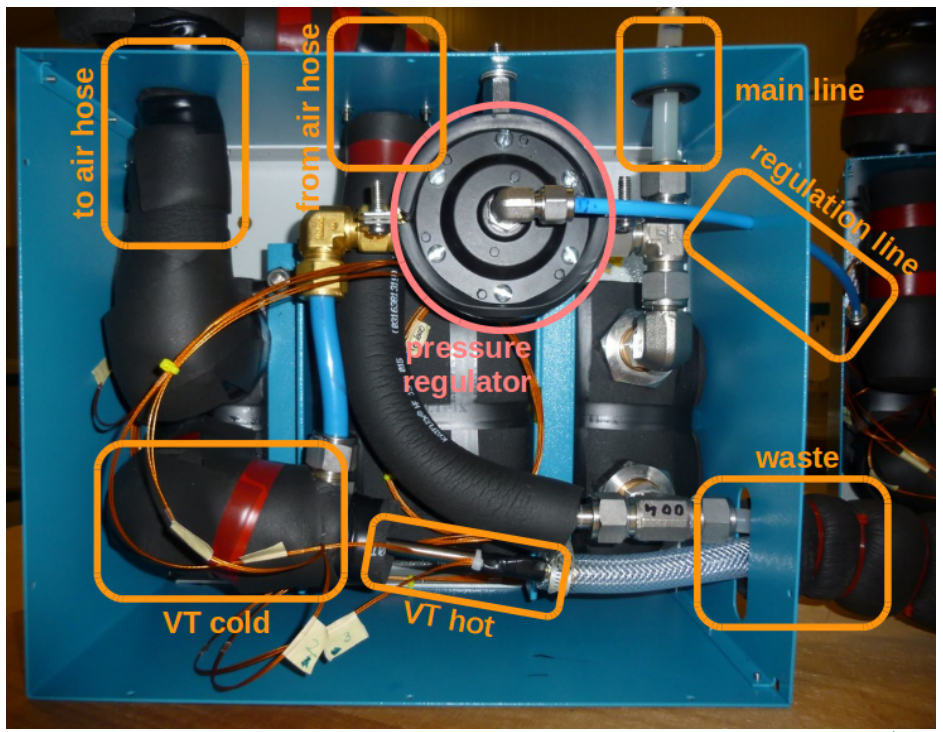


AFP: Cooling System



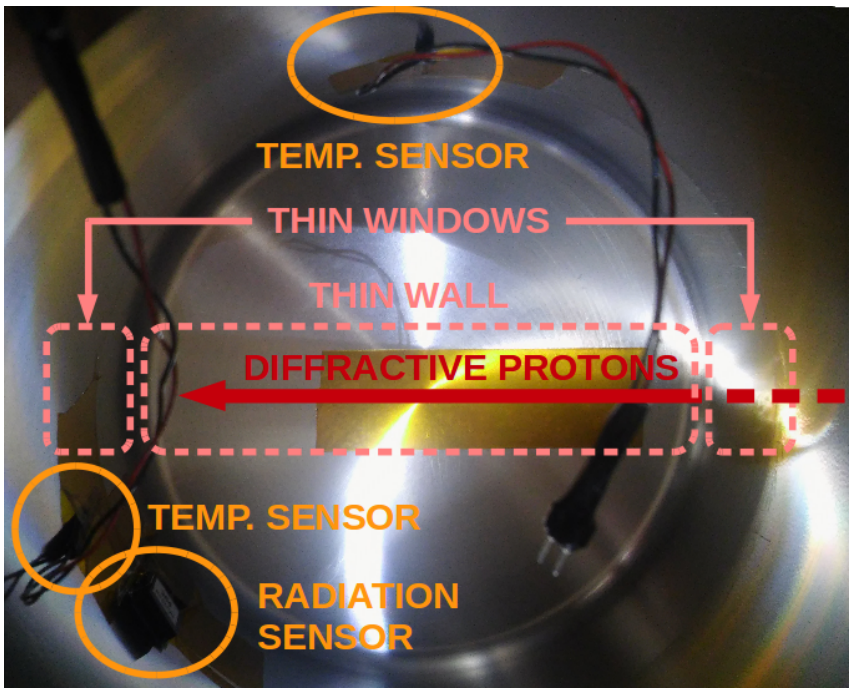
- Technology: Vortex Tube.
- Staged approach:
  - precooling of input air in AirCooler box,
  - cooling with Vortex tube installed on RP.
- Efficient cooling: temp. down to -30 ^{0}C with detectors powered on.
- Operational requirements: -10 ^{0}C.
- Online temperature regulation with PID algorithm.





Temperature sensors (NTC):

- each station:
  - each SiT detector (on flex),
  - ToF (on amplifiers),
  - heat exchanger (NTC + PT1000),
  - pot wall (up + under second thin window),
  - flange (cold output of Vortex tube + HV for ToF),
  - LTB.
- VReg. crate.
- AirCooler box:
  - hot output of VT,
  - cold output of VT,
  - output of box.

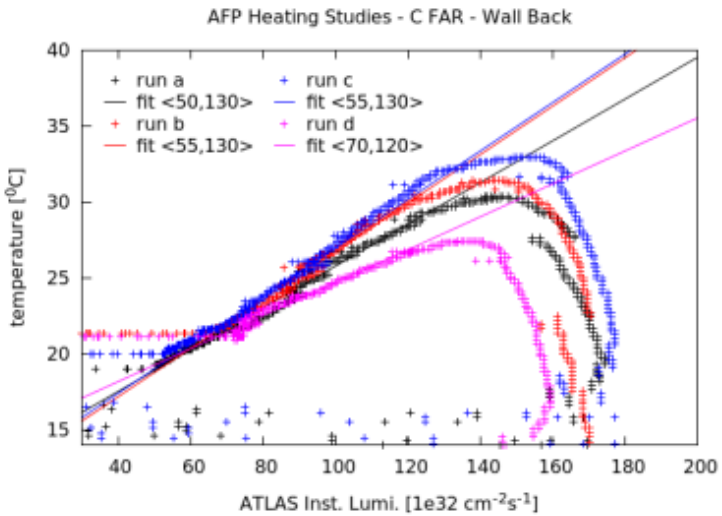


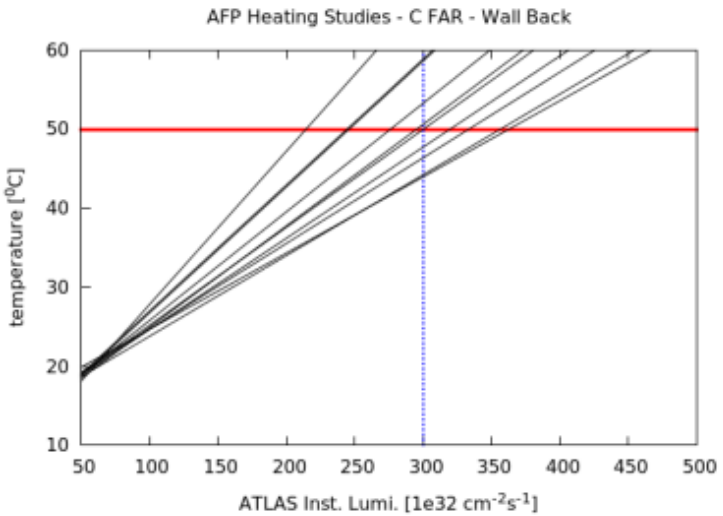
Radiation sensors:

- bottom of each pot,
- VReg. crate,
- far station LTB,
- RR17 alcove.

Pot Heating

- In Run 3 LHC will operate at higher intensity than in Run 2.
- This may increase temperature on SiT $\rightarrow$ hope to be solved by installing new heat exchanger made from foam.
- Another concern is heat induced on RP.

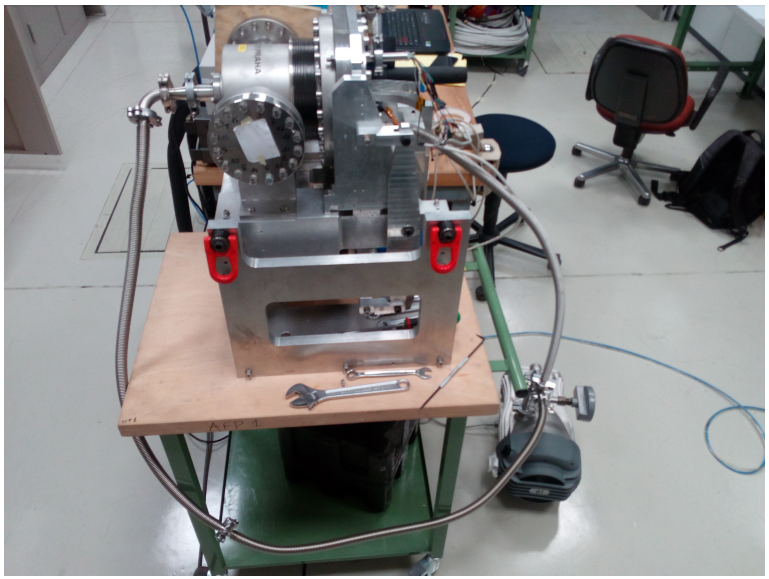


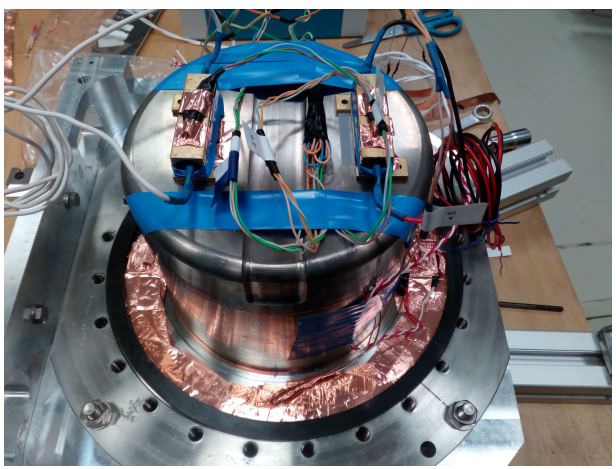


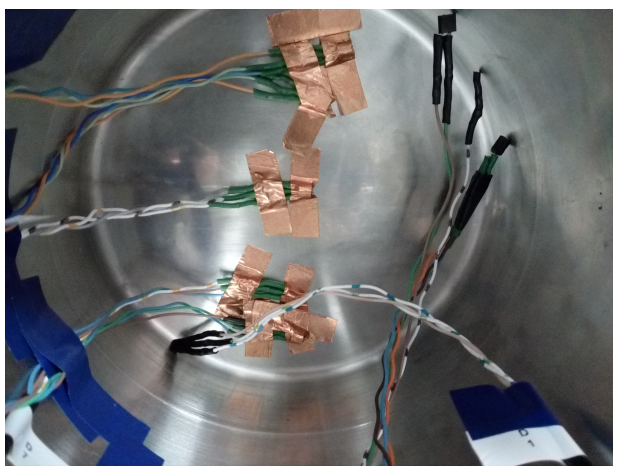
- Example – temperature on C FAR station during four LHC fills taken in 2018:
  - at the beginning (highest luminosity) pot is pre-cooled to 15-20 ^{0}C,
  - as time passes, beam heats the pot more than it can be cooled,
  - at one point there is equilibrium state between dissipated power (coming from the beam) and cooling system $\rightarrow$ an expected, linear dependence between luminosity and temperature,
  - this can be extrapolated to higher intensities,
  - however, reality at Run 3 will be even more complicated due to lumi-levelling.
- Extrapolations based on Run 2 data are not conclusive.

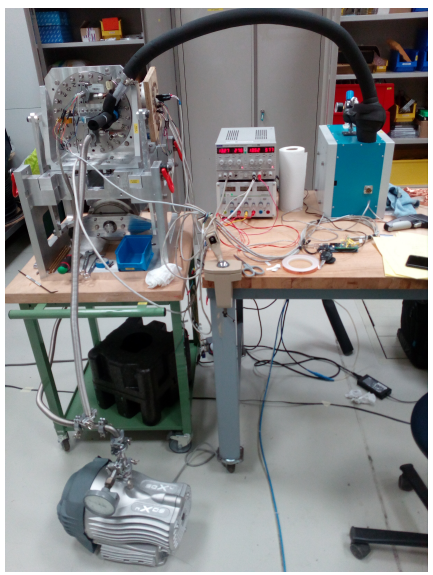
Testbed in B180

- In August 2019 we've lunched a mini-campaign in our lab with a goal to simulate the heating-up of pot and to test few solutions to dissipate induced heat.
- Setup, based on spares mimicked the real configuration in the tunnel (station, vacuum, cooling unit).
- A number of heaters (individual regulation) and temperature sensors were installed.
- With such setup various heating scenarios were tested.



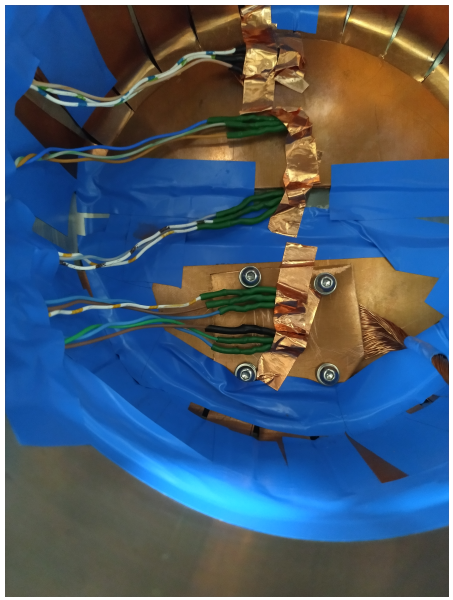


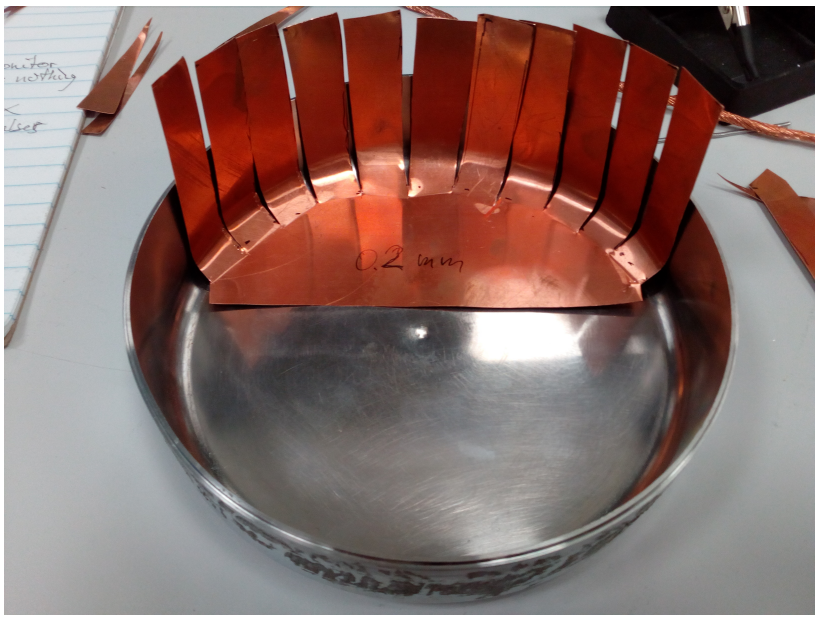


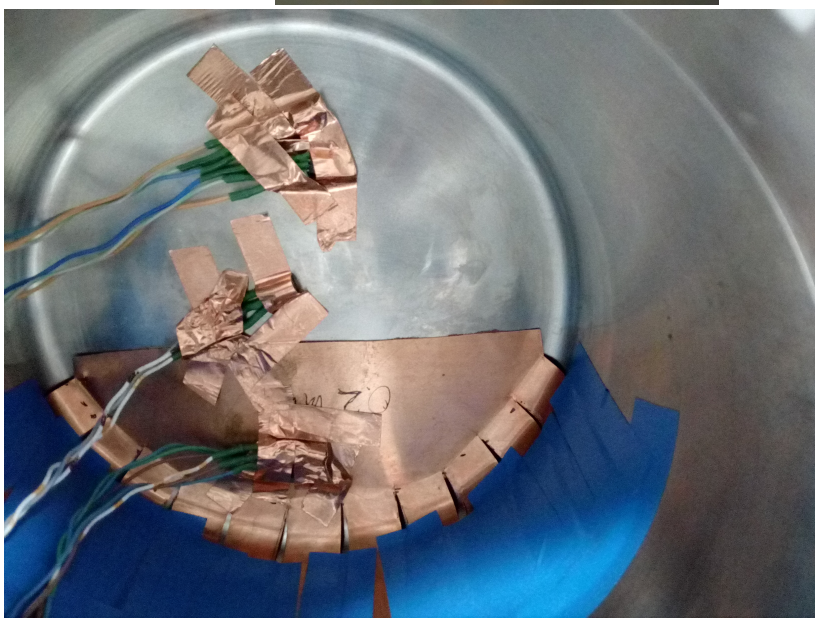


Test of Heat-sinks

- Several heat-sink solutions were tested assuming various location of heat source.
- As the exact design of the heat-sink depends on the heat source and expected amount of power to be dissipated, decision was to:
  - prepare special temperature sensor setup to investigate temperature gradient in the pot with real data (first year of Run 3),
  - design adequate heat sink, if needed (based on Run 3 year 1 data).

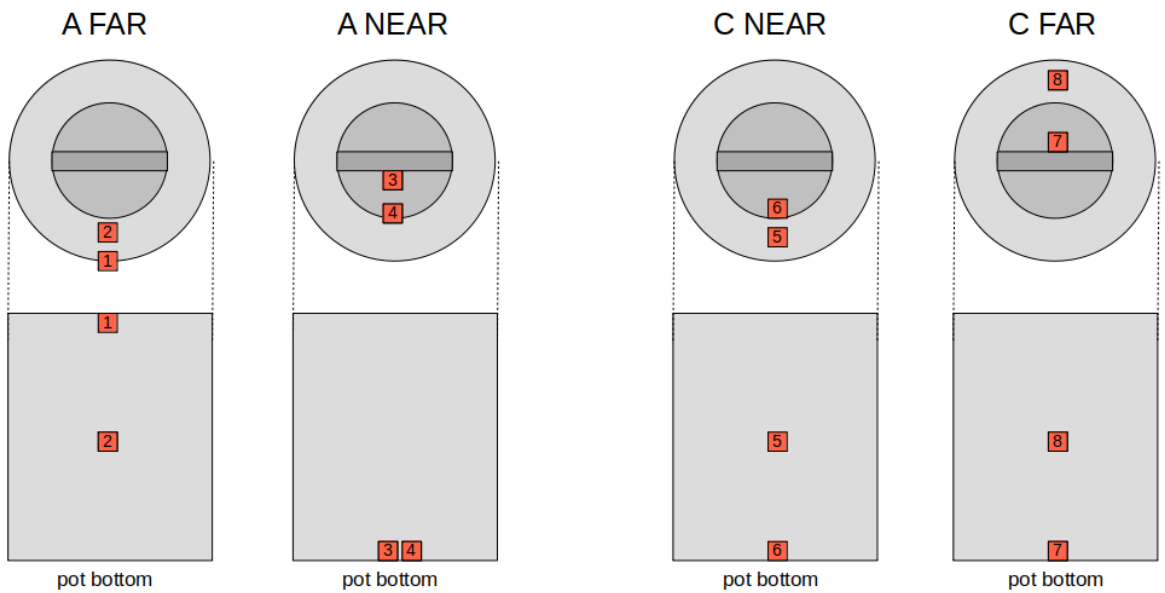


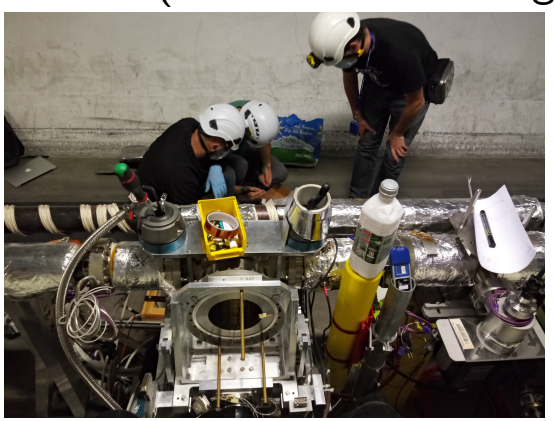


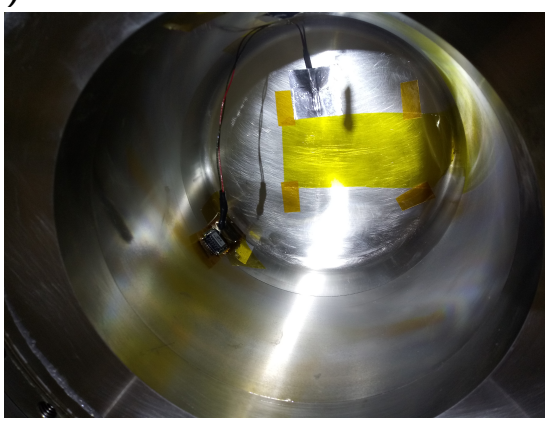


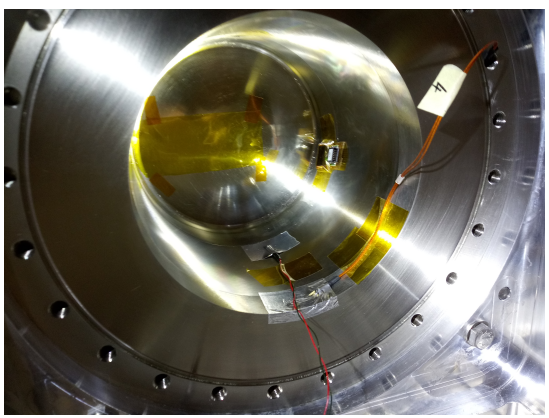
New Placement of Temperature Sensors Inside Pot

- During installation of detector packages (Mar. '20 and Sep. '21) temperature sensors inside pots were placed in a special way.
- This should allow, based on 2022 data, to understand:
  - where exactly heat is induced,
  - need of heat-sink for 2023-2025 data-taking (and if so – its design).

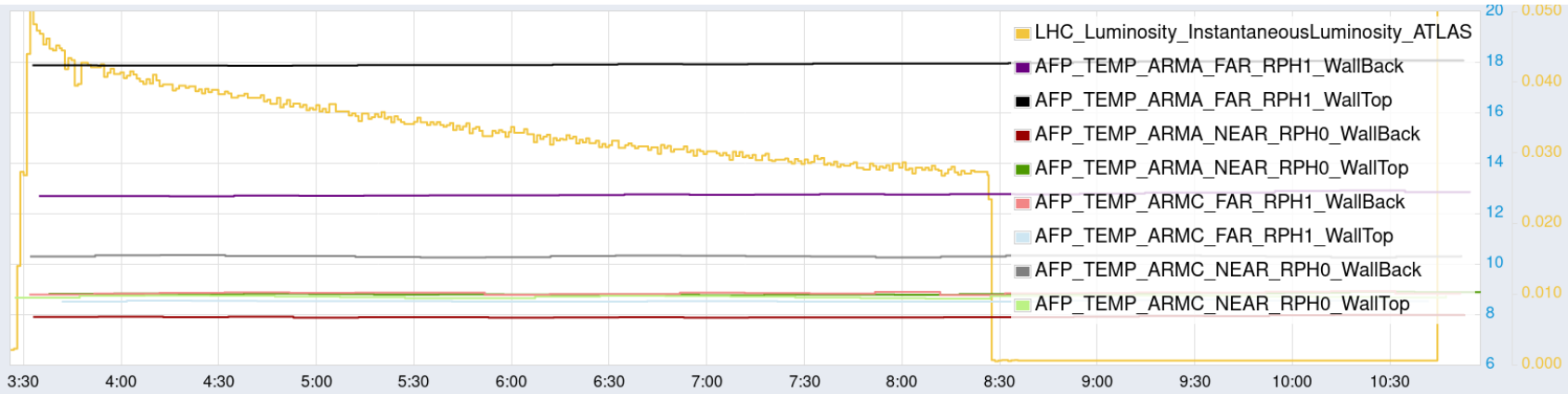




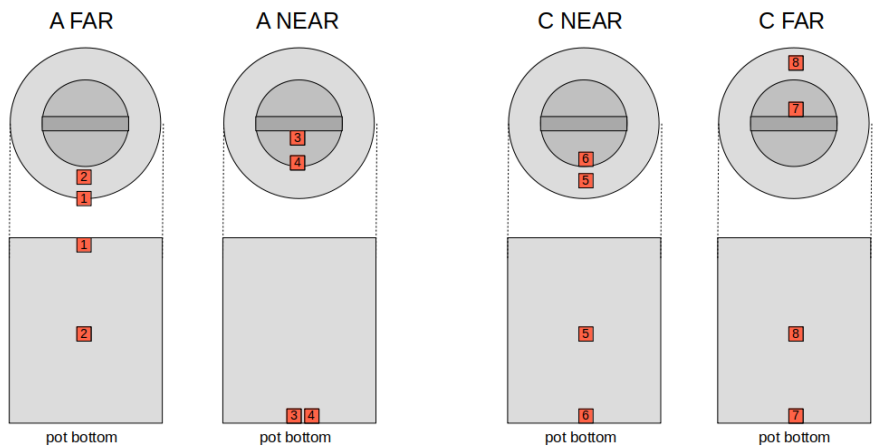




- AFP was inserted 16-20 mm from the beam during the pilot beams.
- A quick look at pot heat was taken, but (as expected) the effect was not visible (small beam intensity, large pot-beam distance).
- A real campaign will be lunched during the first intensity ramp in 2022.



1 Down Wall Flange former wall top on A FAR
2 Down Wall Middle former wall back on A FAR
3 Down Bottom Thin Window former wall back on A NEAR
4 Down Bottom Wall former wall top on A NEAR
5 Down Wall Middle former wall back on C NEAR
6 Down Bottom Wall former wall top on C NEAR
7 Up Bottom Thin Window former wall top on C FAR
8 Up Wall Middle former wall back on C FAR



Summary

- AFP detectors will take data during (almost) all fills with STABLE BEAMS in Run 3.
- When operating in a close vicinity of LHC beam, Roman pots are heated.
- AFP cooling system actively keeps temperature of about -20 ^{0}C on the detectors and passively cools the pot.
- Extrapolations based on Run 2 data are not conclusive:
  - luminosity levelling may introduce additional, non-linear effects.
- Effect of heat induction will be studied using data-driven methods starting from first intensity ramp in 2022:
  - special setup of temperature sensors inside AFP pots,
  - quick look on pilot beam data was done, but no conclusions can be made (as expected due to large pot-beam distance and low beam intensity).
- Several heat-sink solutions were tested during 2019 mini-campaign in the AFP lab.
- Depending on the measured data, the following scenarios are considered:
  - no special action – in case of being cooled enough with the existing setup (note: new heat exchangers installed in LS2),
  - design and installation of heat-sinks during YETS 2022-2023 in case heat from pot bottom needed to be dissipated more effectively.