Beam scraping in the SPS for LHC injection

Collimation and safety issues.

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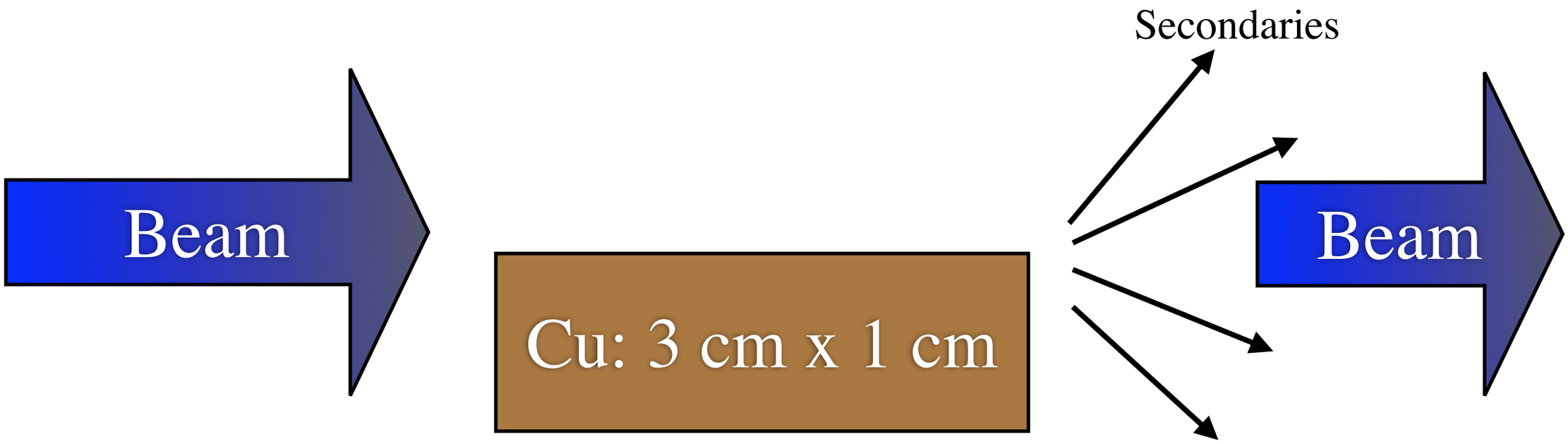
Outline

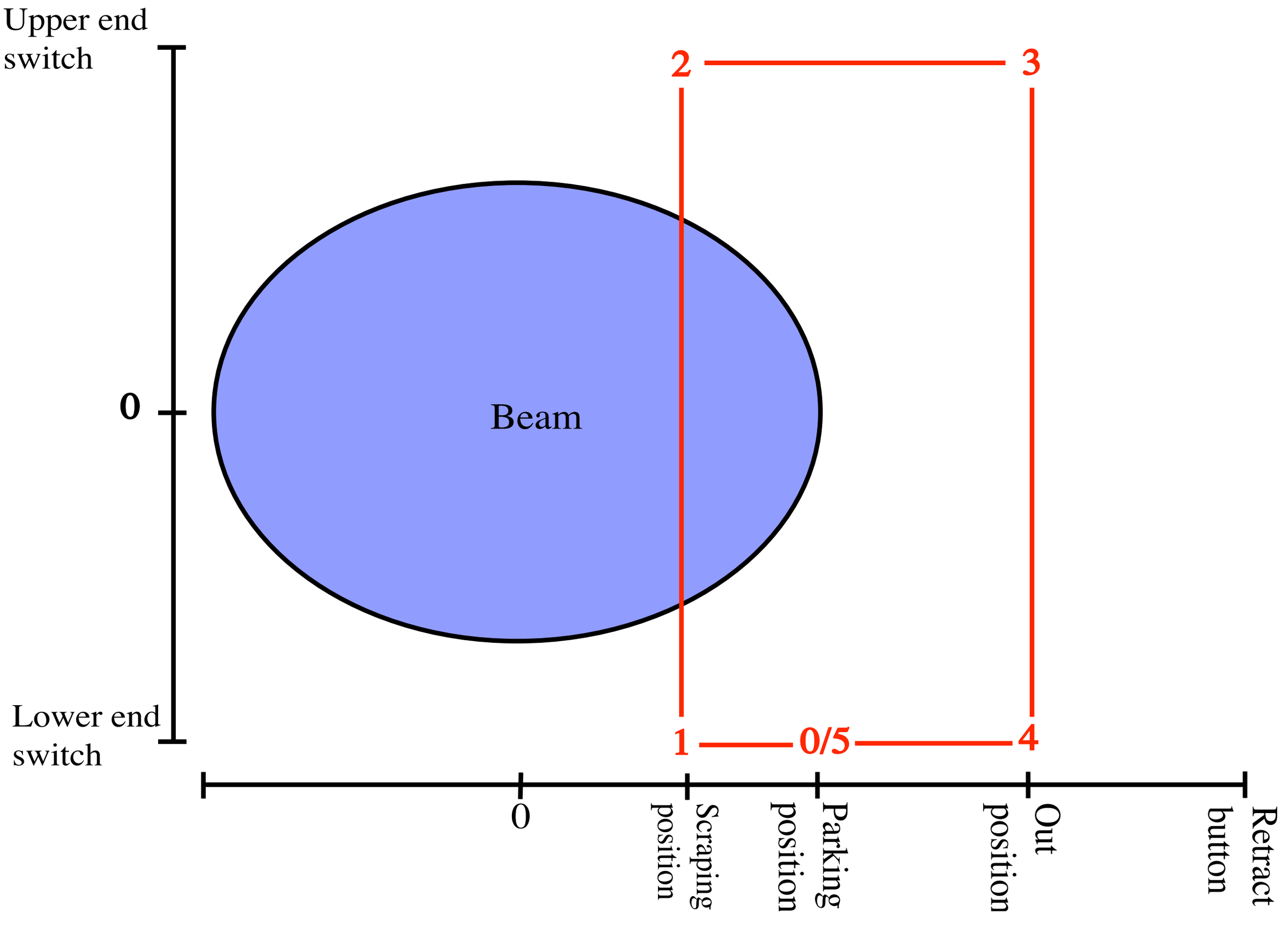
- “Scraper mechanics”
- Beam interaction with scraper
- Loss maps when scraping
- Preliminary conclusions and outstanding issues

Physical properties and interactions



- Elastic multiple scattering (nuclear + EM, RMS scattering angle ~44 microrad)
- Inelastic processes (18% probability per pass)
- Stopping power: EM, avg. loss ~54 MeV per pass
- Avg. loss from EM+nuclear: ~265 MeV per pass

Beam scraper movement



FLUKA sim: Nominal LHC beam impact on scraper

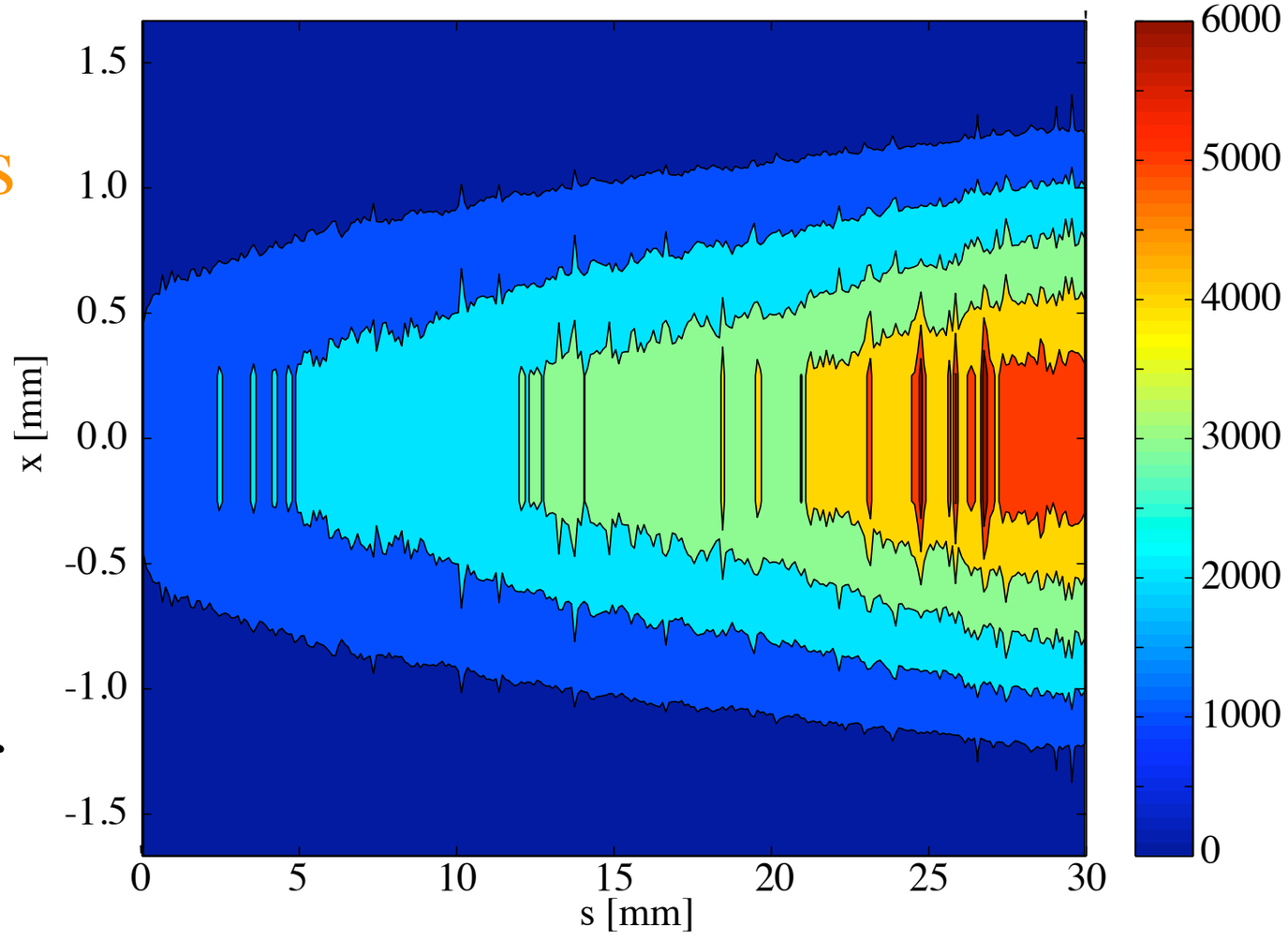
Heat req. to increase T by 550 K = heat of melting

$$T_{melt}(\mathrm{Cu}) = 1358\,K$$

V. Kain et al *(LHC Project Report 822)*: Melting in Cu after 3x24 mm with 1/4 of LHC beam intensity @ 450 GeV. Suggests melting in scraper after ~10 mm.

Right: Adiabatic FLUKA simulation (by R. Bruce) with constant heat capacity. Heat of melting not included in plot.

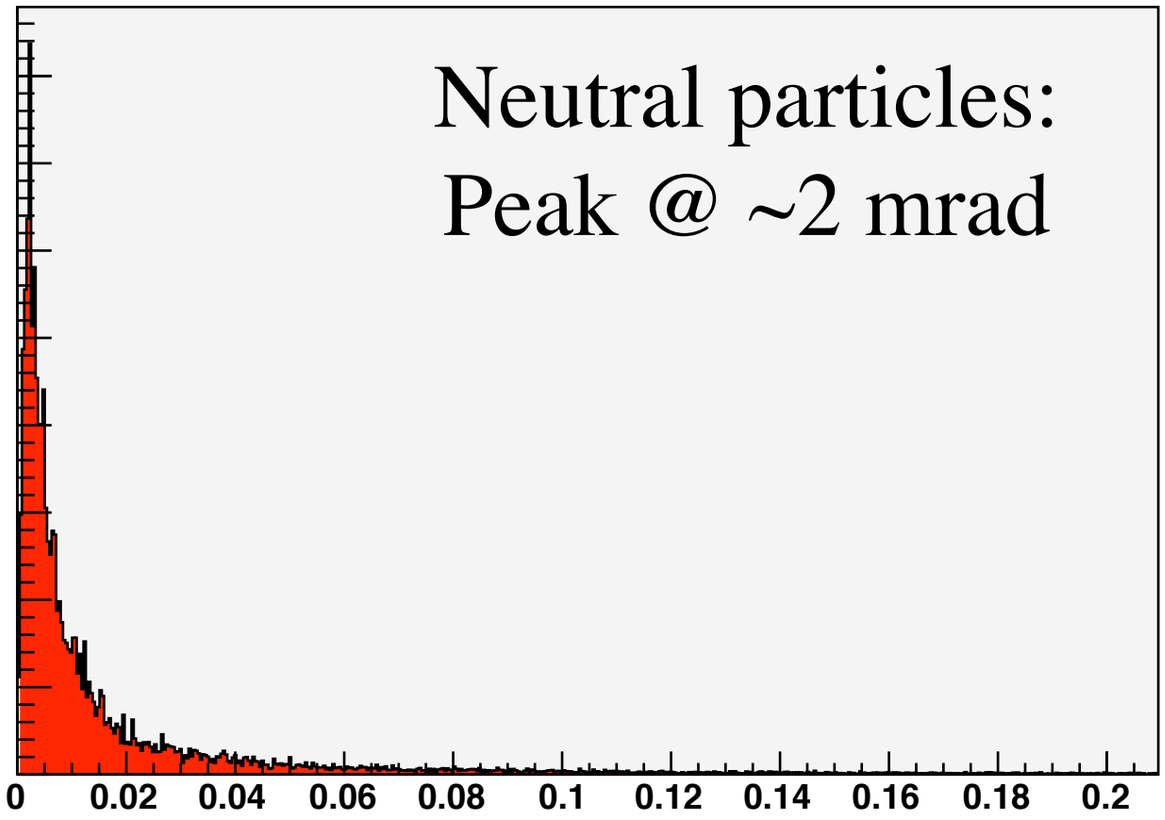
Scraper jaw temperature increase

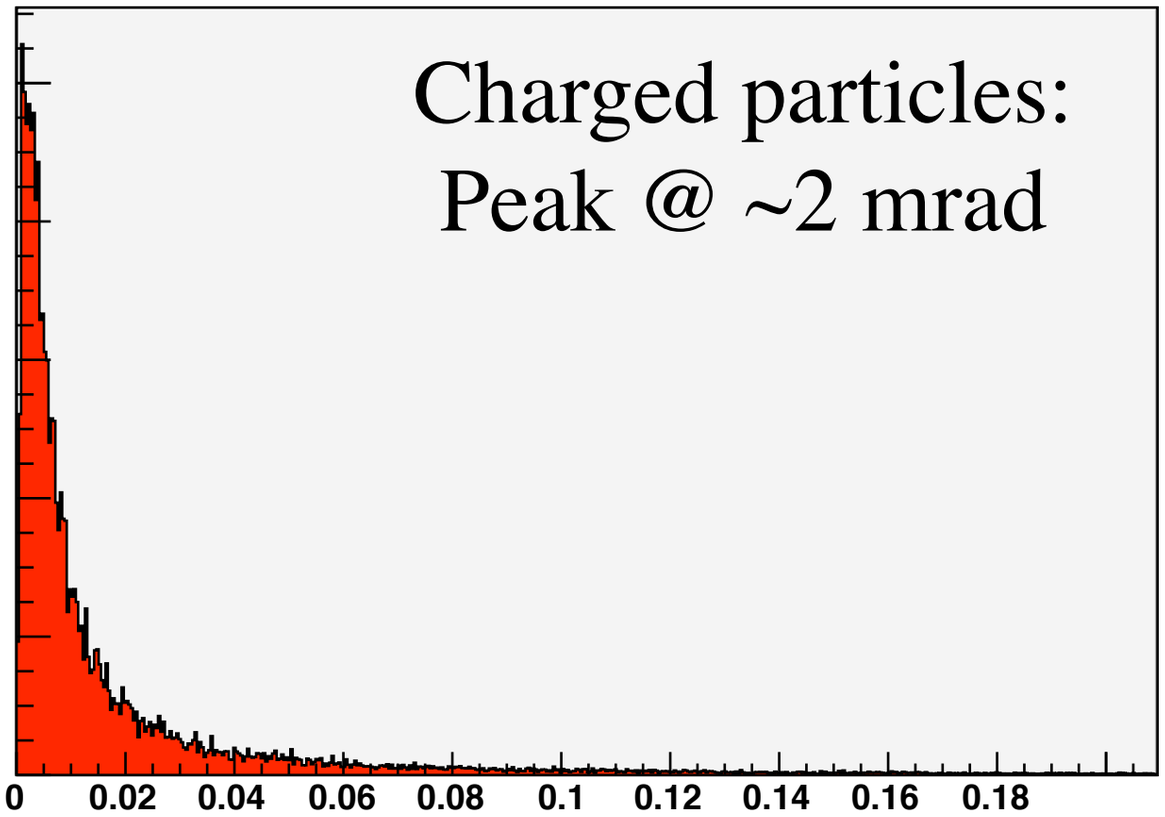


Comments on heating

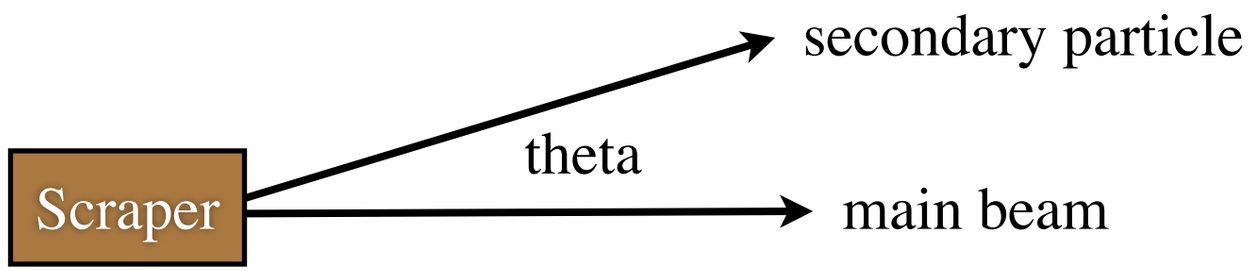
- On the bad side:
  - In a ring, the beam makes several passes (this was one)
  - Most protons hit sharp corner of scraper
- On the good side:
  - Only very small volume affected
  - The scraper moves ~5 micrometer per turn, and beam size will increase (meaning heating will spread somewhat)
  - Collimators and aperture will take some of the heat load
  - Beam tails are expected to be >1% of total beam intensity
  - 450 GeV beam does not “jump around”

Geant4 sim: Energy of secondary particles from nuclear interactions - angular distribution





- Angular energy distribution peaks at 2 mrad
- This gives 10 cm spread after 50 meters

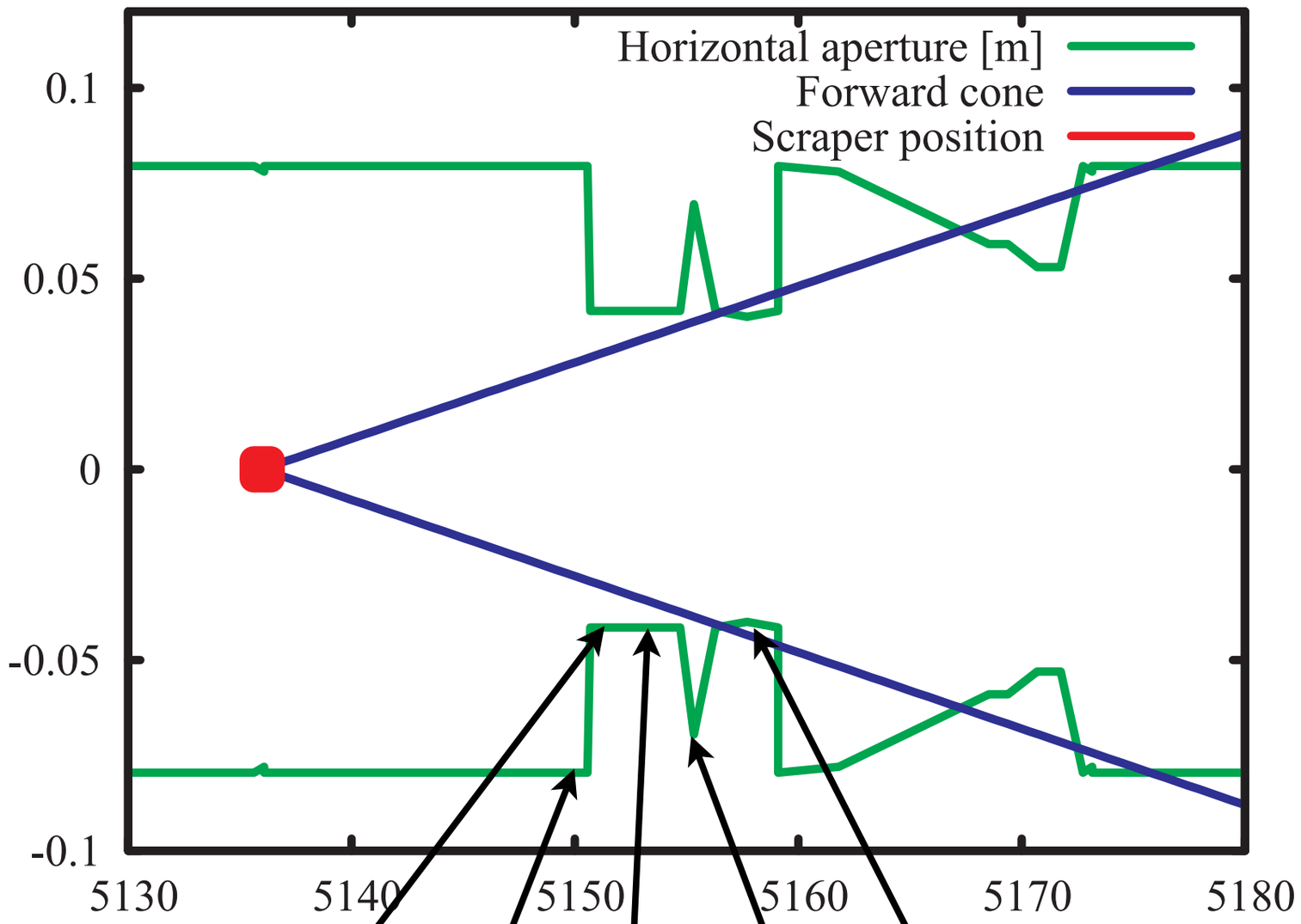


SPS aperture in point 5

Scraper at 5136 m.
Secondaries from scraping end up in aperture elements within ~25 m.

But collimators are at:
Primary: 5213 m
Secondary: 5277 m
Arc starts: 5254 m

Forward cone = peak in previous slide



V kicker + BPM

BPM

Quadrupole

Wire scanner

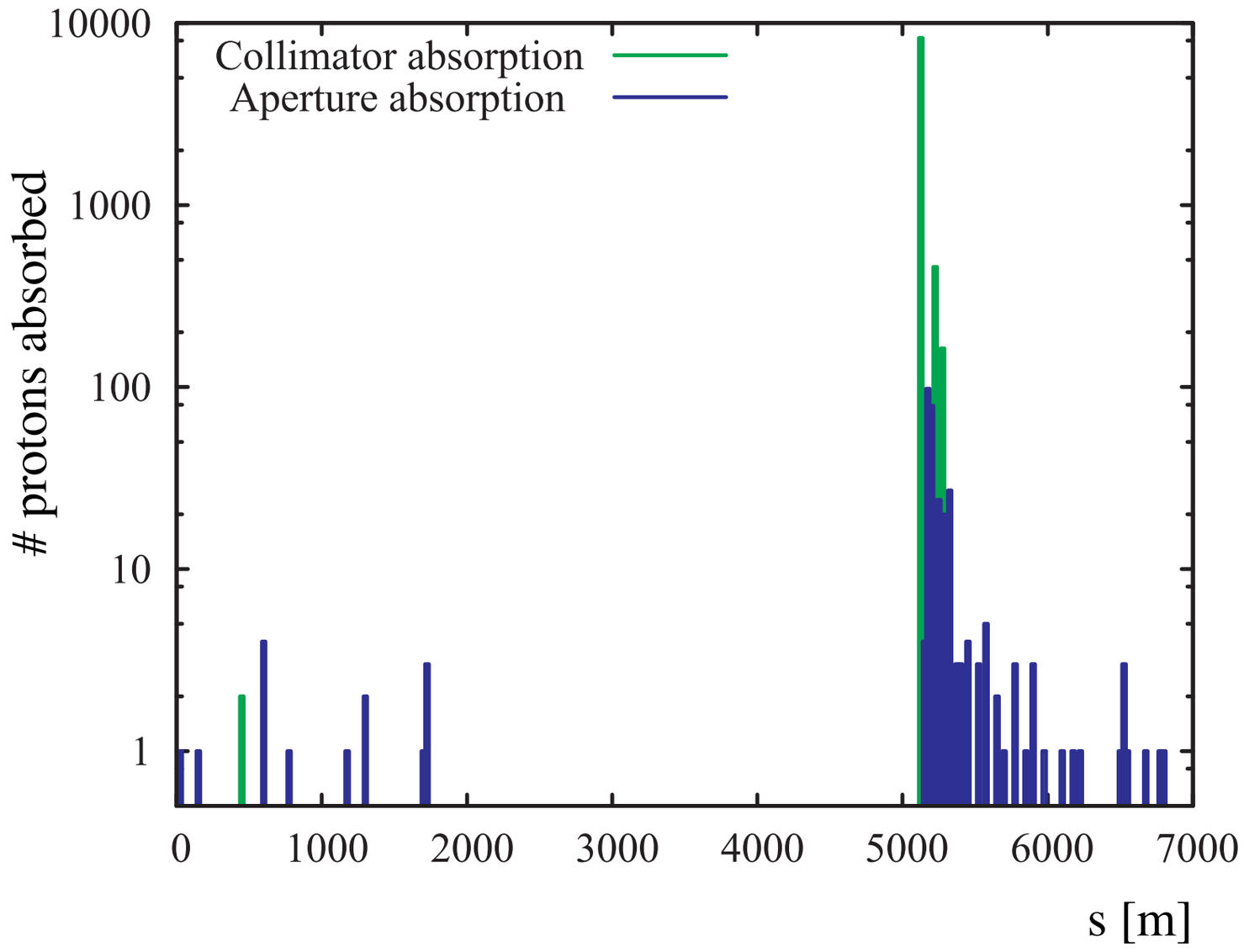
3 kickers

Safety considerations

- Scrapers themselves may be damaged if scraping more than ~10% of nominal LHC beam (exact limit not known yet): Should not be used for beam shaping
- Secondaries from scrapers: A lot of energy in the showers, but over a large area
- "Simplest" solution to problem: Dump beam if too much is scraped!
  - Is the current beam interlock system capable of this?

SixTrack loss map

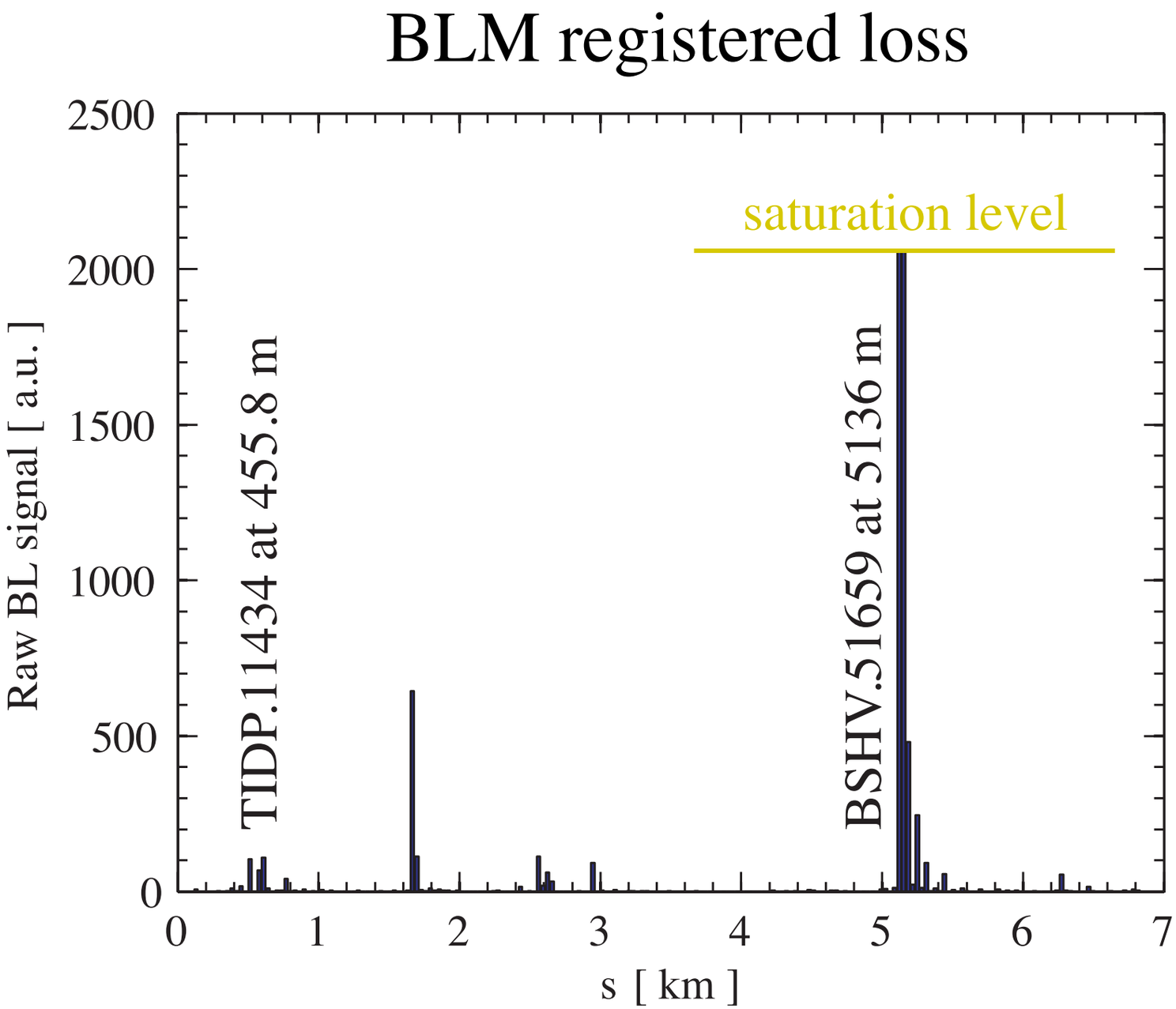
Preliminary results:
90% of lost protons have nuclear int. in scrapers
Aperture absorbs about the same as collimators
(In addition: Secondaries from scraper hitting aperture a serious issue)



This simulation:
10k protons, halo at 4 sigma with 0.5 sigma smear
Collimators as close as injection optics permit
Horizontal scrapers at 3.5 sigma
*(*see *Scraper functional specification* by *H. Burkhardt, G. Arduini)*

Loss map from MD, Sept. 12, 2007

- Results not dissimilar from simulations: Huge loss after scrapers
- If you zoom in: 2 BLMs immediately after scraper have the largest losses - before collimators!
- In this plot: Collimators at injection compatible settings
- See *H. Burkhardt et al., LHC Project Report 1022*

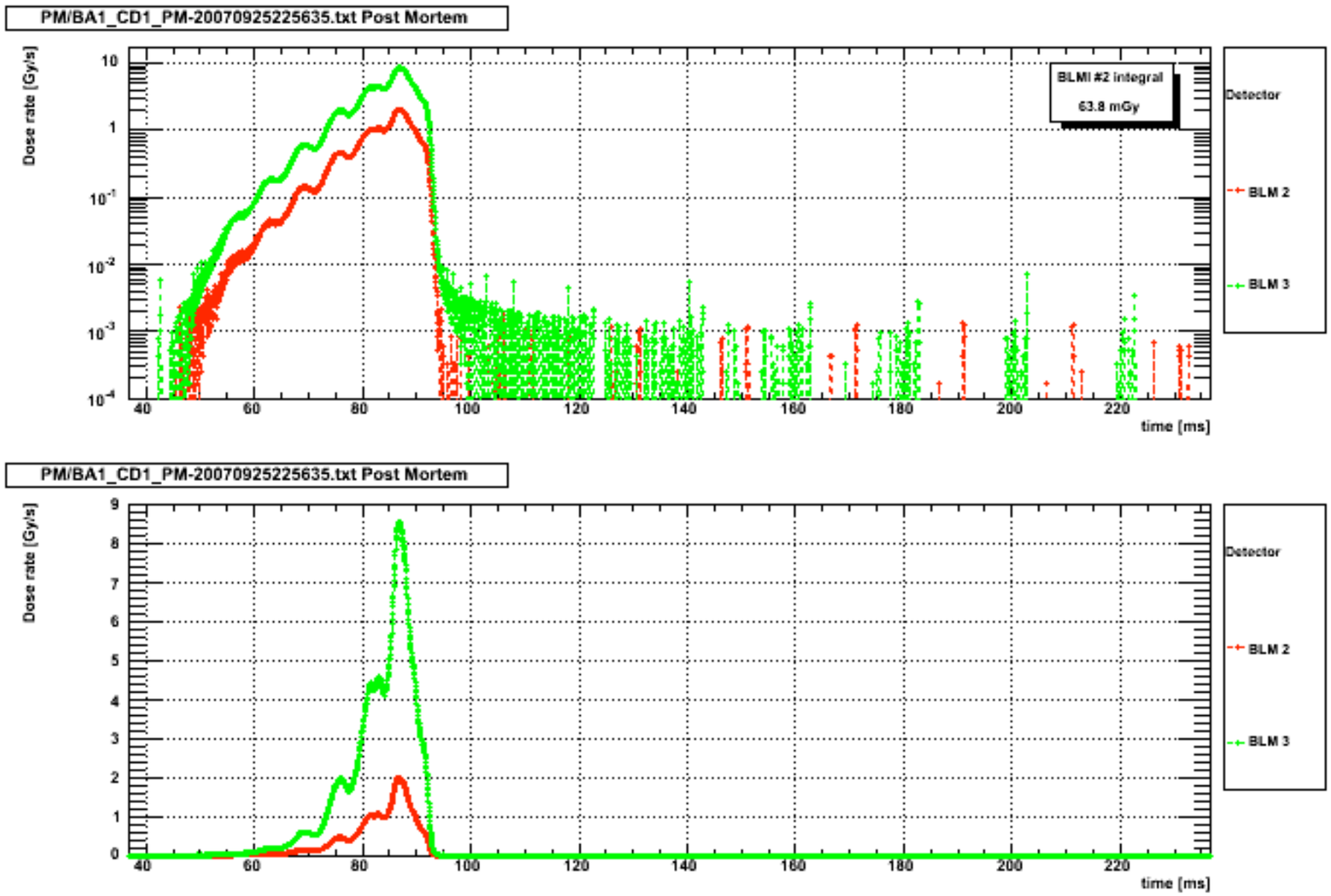


Time dependence of scraping

Timescale:
~50 ms or
~2000 turns

Scraper moves at ~20 cm/s, 2sigma diameter of beam: 2.4 mm or ~3000 turns

Dose rate as function of time when scraping



Plot: Thanks to D. Kramer

Different slopes on left and right of peak: Beam entry and absorption?

Preliminary conclusions

- Scrapers will be damaged if intercepting high intensity beams
- Most of the scraped beam's energy is deposited as secondaries from the scraper itself, hitting local aperture
- Primary and secondary collimators of little importance when scraping - aperture absorbs same number of protons
- Momentum collimator intercepts very little, if anything

Outstanding issues

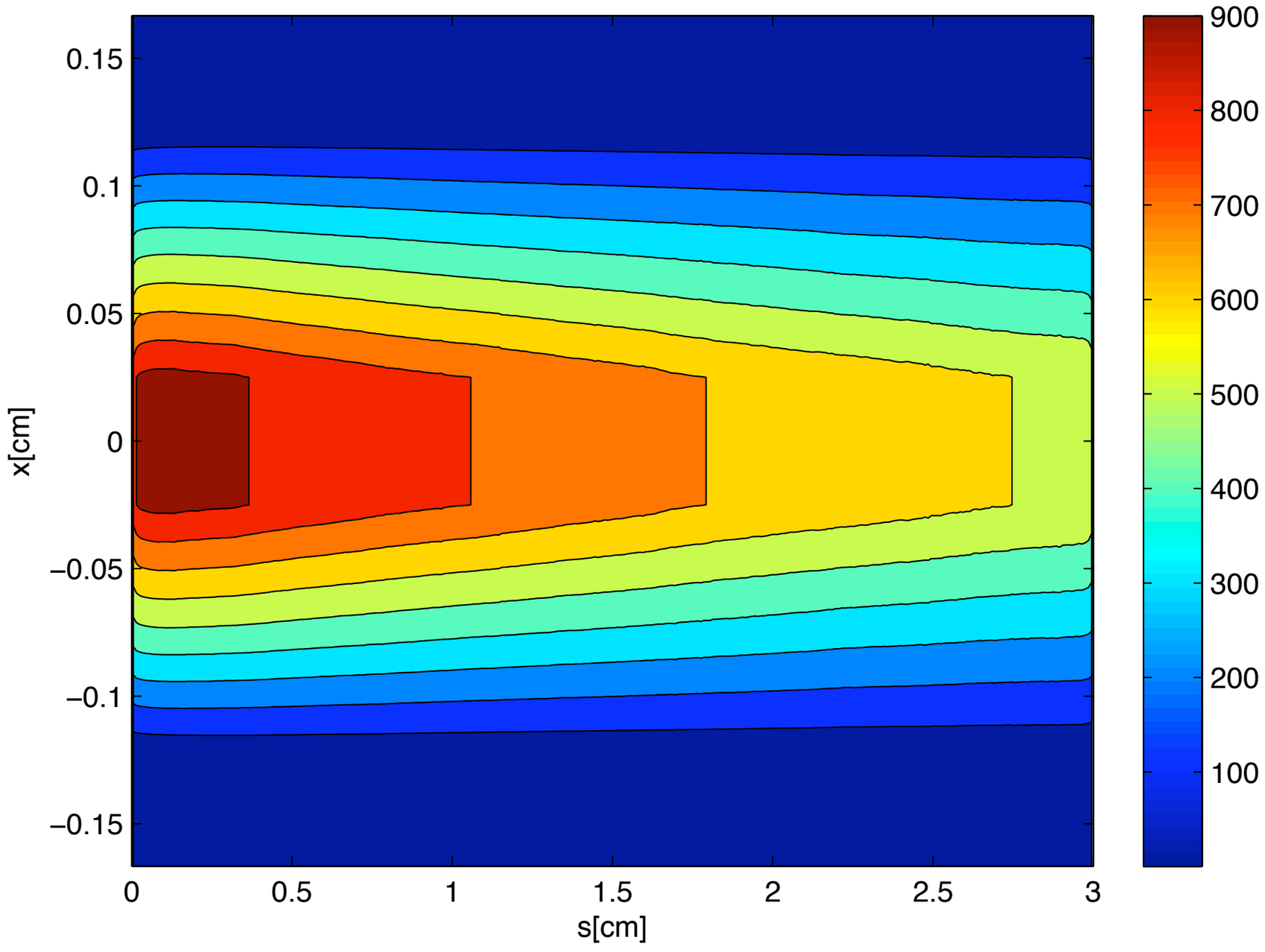
- Safety of hardware: Is the beam interlock system sufficient as it is today?
- Can instruments/aperture downstream be damaged? (Gut feeling: No)
- Do we need more accurate loss maps (experimental and/or simulated)?
- Do we need to understand tail repopulation?

Possible future work

- Understanding tail repopulation and scraping time dependence
- Tracking and Monte Carlo to get loss maps and more detailed information on energy deposition
- Ideas and design for new scrapers
- Feedback and suggestions from the audience appreciated!

Backup slides...

LHC nominal ion beam impact



Note: $T < T_{melt}$

BLM data, MD 12.09.2007

Plot: Thanks to D. Kramer