Past experience with the present scraper

As presented in LTC 21 May 2008, with minor updates

- **Short introduction**
- **References, links to talks**
- **Status and few observations**
- **Known issues**
- **Follow up**

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Arnaud Brielmann / ATB, Francesco Cerrutti / STI ; LHC collimation team

SPS Scrapers for LHC injection

For diagnostics and quench protection at injection in the LHC

Make sure the beam sent from the SPS is clean

with numbers, same as in spec, APC 8/6/2006 ...

Nominal LHC injection: 288 bunches of 1.15×10^{11} protons in 4/11 of an SPS turn or 7.86 μs together 3.3×10^{13} protons. Quench level ~ 5×10^{9}.

1.5×10^{-4} of single shot of nominal injection is sufficient to quench the LHC.

There are special devices to protect the LHC from destruction by injection failures like TDI (only in V, protection from kicker failures) and TCDI (transfer line collimators, protection against destruction of septum and injection region) to dilute the beams to levels below destruction .

Cold (arc) apertures, tightest at injection in the LHC, ~ 7.5 σ and rather exposed, particularly on first ~ half turn before injected beams reach collimation insertions.

Tails beyond ~ 3 - 3.5 σ not useful for luminosity - only increase risk for quench and radiation. Remove as early as possible.

References and links to presentations

References

J. Gareyte, “Requirements of the LHC on its injectors", Chamonix IX, CERN-SL-99-007 DI p. 41-46

P. Collier, “Controlling the beam for extraction: Do we send it?", Chamonix XI, CERN-SL-2001-003, DI p. 83-87

H. Burkhardt, “Collimation Issues at the SPS and in the Transfer lines", Chamonix XIII, CERN AB/2004-014 (2004), p. 101-105

Intensity and Luminosity after Beam Scraping ; H. Burkhardt and R. Schmidt, CERN-AB-2004-032-ABP

Functional Specification, G. Arduini and H. Burkhardt, EDMS doc # 772782, Feb. 2006

Burkhardt, Arduini et al., Beam Scraping for LHC Injection, PAC 2007

P. Letnes, *BEAM SCRAPING FOR LHC INJECTION: HIGH LEVEL APPLICATION DEVELOPMENT*, CERN-AB-Note-2008-012

P. Letnes, H.B. et al., Beam Scraping to Detect and Remove Halo in LHC Injection, EPAC 2008

P. Letnes, *Beam Scraping in the SPS for LHC Injection*, Master thesis July 2008, CERN-THESIS-2008-053

Talks

H. Burkhardt, The use of the SPS scrapers during early LHC operation, LTC 27/04/2005, slides

C. Fischer, Final results on scraping in the SPS, APC 23/06/2005

H. Burkhardt, SPS scraper MDs, APC 08.06.2006, slides

H. Burkhardt, Measurements with the scrapers in the SPS, APC 13/04/2007 APC, slides

P. Letnes, MDs with the Scraper at the SPS, APC 26/10/2007, slides

P. Letnes, Scraping in the SPS for LHC injection, ABP-LCU meeting 5/11/2007

P. Letnes, Beam scraping at the SPS, Collimation WG meeting on 04/02/2008, slides

H. Burkhardt, Update on SPS scrapers for LHC injection, LTC 21 May 2008.

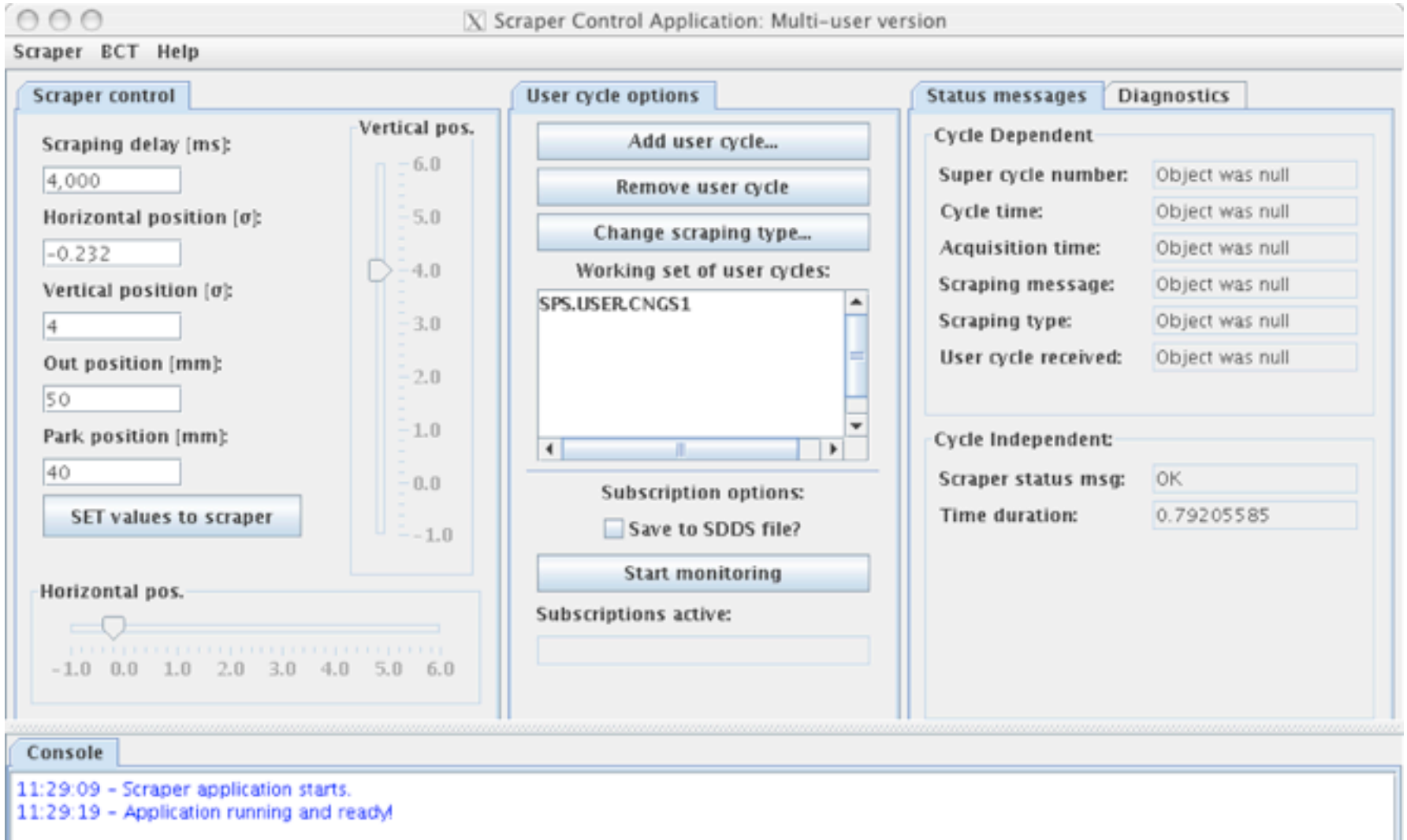
P. Letnes, *Transverse Beam Scraping in the SPS for LHC injection: Efficiency and Robustness Studies*, AB Forum 10/06/2008

Status

Hardware : H/V scrapers and (LEP) collimators in final positions since 2006, scraper 51659, coll 51899-52105
45° installation was staged - remains to be completed

Low level software written by S.Bart-Pedersen et al. / BI, successfully used / tested in 2006 / 2007

High level application written and tested by P. Letnes et al. in 2007-2008, link to the software
+ documented for Master thesis + CERN-AB-Note-2008-012, http://cdsweb.cern.ch/record/1092915

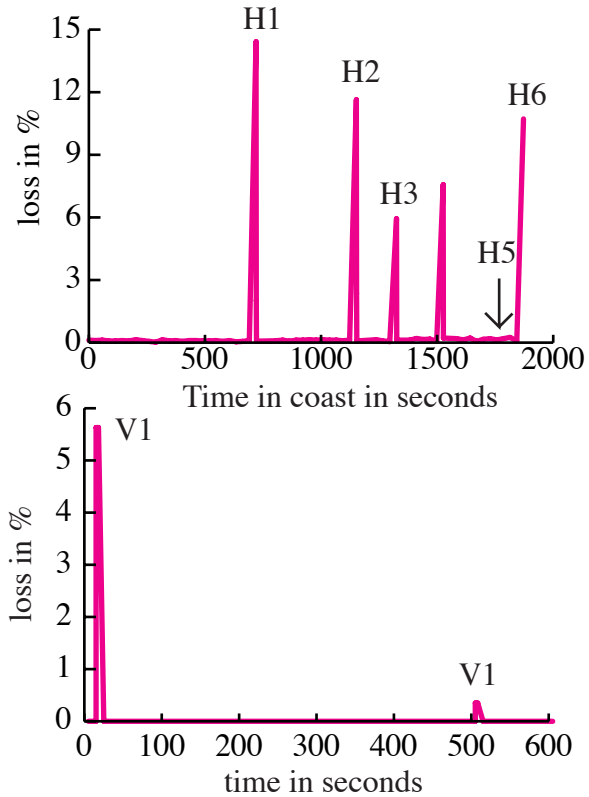


Observations, tails and re-population

Tail re-population

Horizontal plane :
To our surprise, we found significant tail re-population of the order of $2x10^{-3}$/sec. Changing tunes and turning off the rf-voltage had no significant effect. A possible cause is the transverse feedback which remained on.

Vertical plane :
5.63% of the initial population was removed in the first scraping. A second vertical scraping after about 8 minutes removed about 0.35% of the beam, corresponding to a tail re-population of $0.007x10^{-3}$/sec or 200 less than in the horizontal plane.



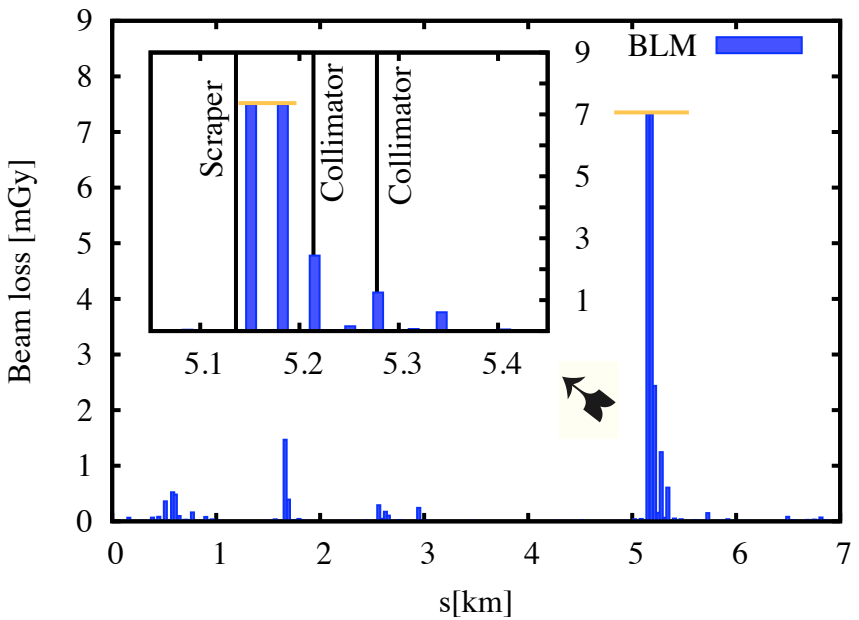
Repeated scraping at the same position in Horizontal and Vertical plane

as presented at PAC 2007

also observed with feedback off - source not yet identified. ripple and / or intrabeam ? - order of magnitude from growth rates not too far off. Full intrabeam simulations with halo very hard and time consuming, some recent progress :
MOCAC authors P. Zenkevich and A. Bolshakov from ITEP at CERN in January 2009,
CERN fellow Alessandro Vivoli working with Michel Martini for CLIC, recently rewrote intrabeam part in C and simulated SPS injection at 26 GeV, see presentation in CLIC Beam Phys. meeting 13 May 2009

Loss maps around the SPS

data

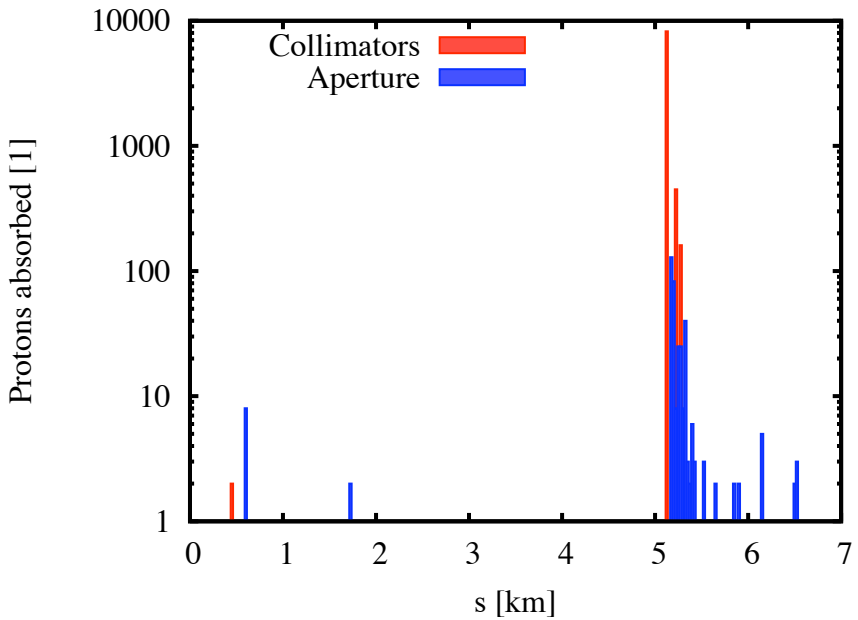


from 12/09/2007

note : y-scale is linear

saturation at 7 mGy

simulation



using Sixtrack

by P. Letnes with help from collimation team

note : y-scale is log

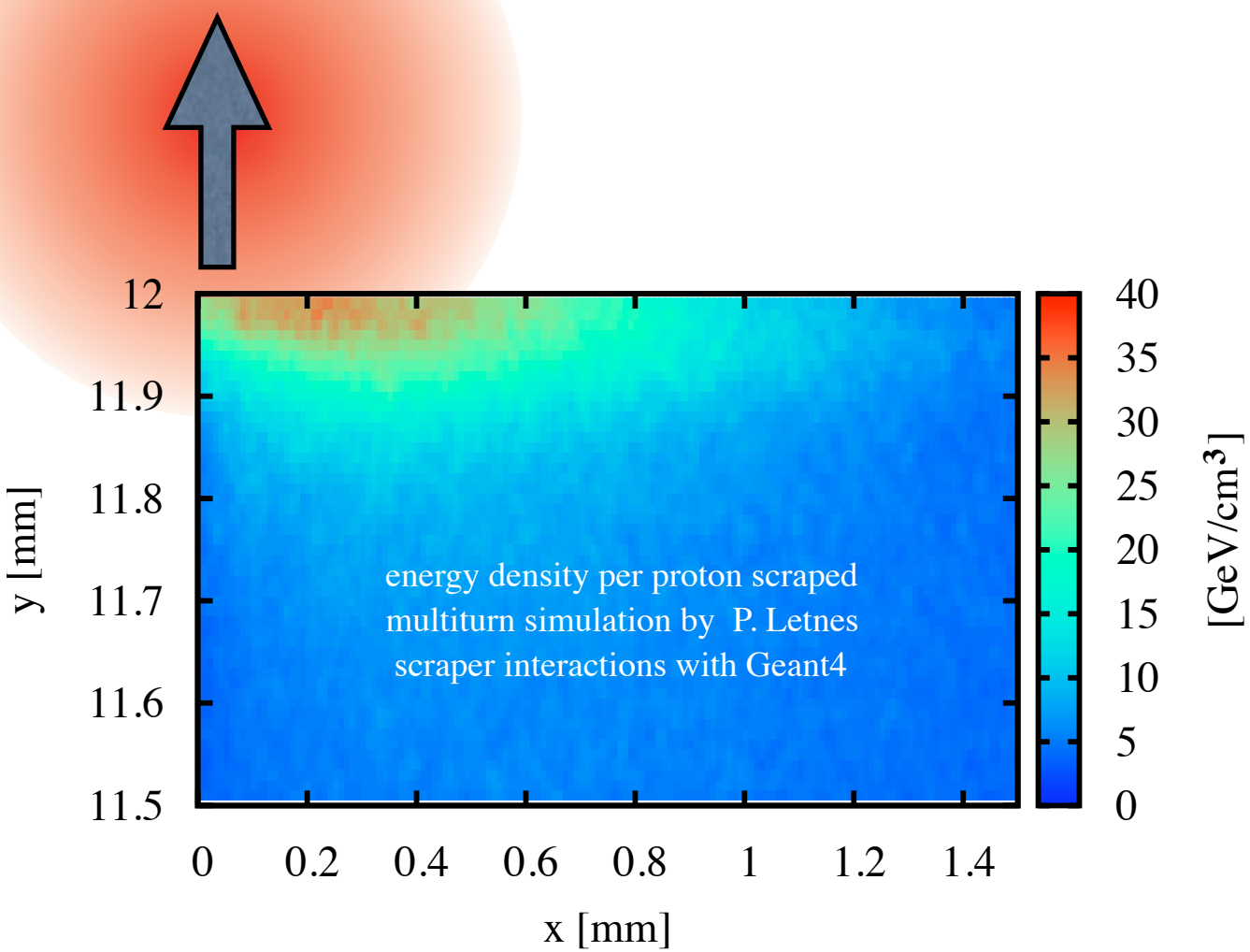
highest losses ~ 80 % in scraper

~ 10 % chamber close to scraper

~ 10 % on collimators

Known issues

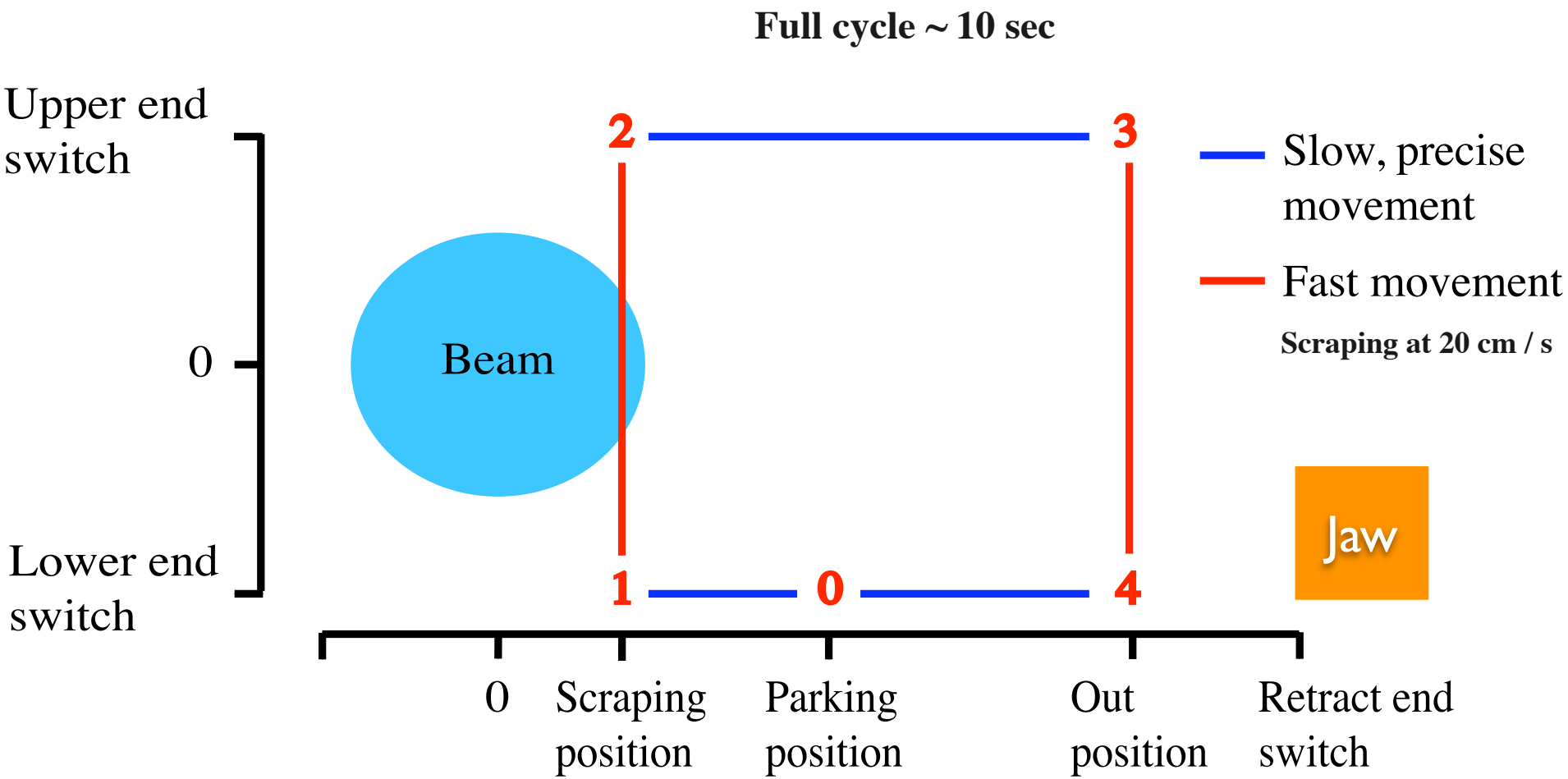
Main issue: scraper risks damage - melting Cu on the surface if moving centrally through the dense high intensity LHC beams



Expected for Gaussian and scraping at 3.5 σ loss of 0.22 %

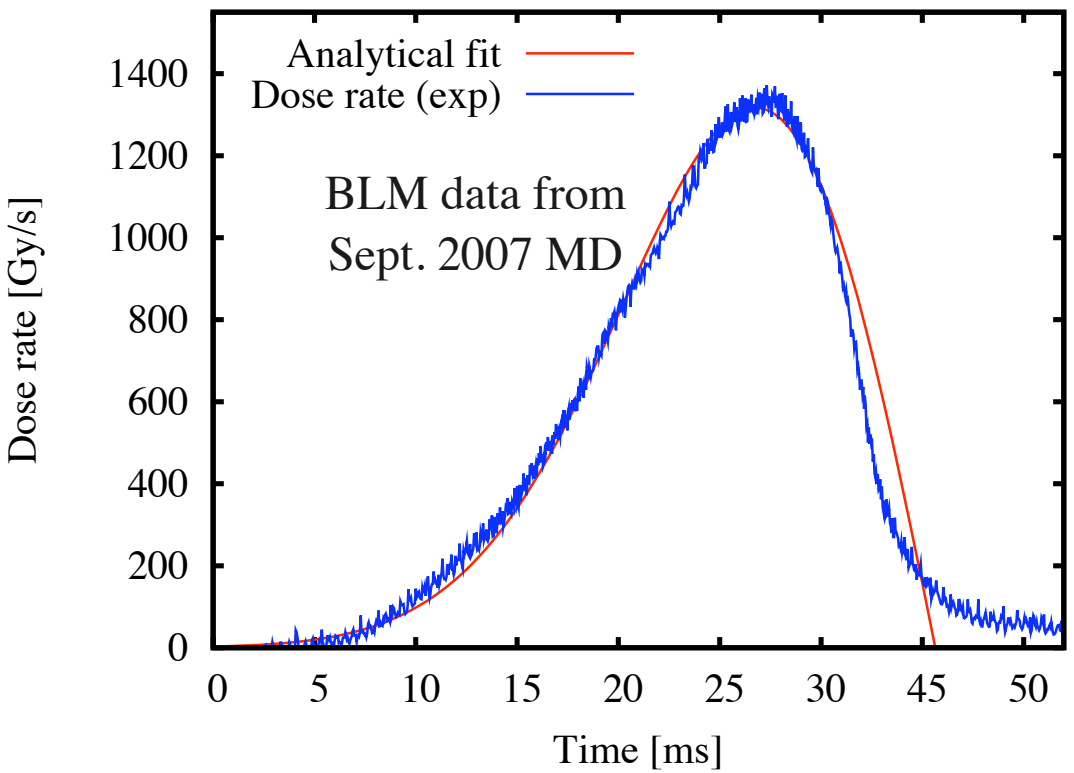
Current scrapers : 3 cm Cu speed 20 cm / s Estimated to be safe to 5×10^{11} or 1.5% of full 288 bunch injection

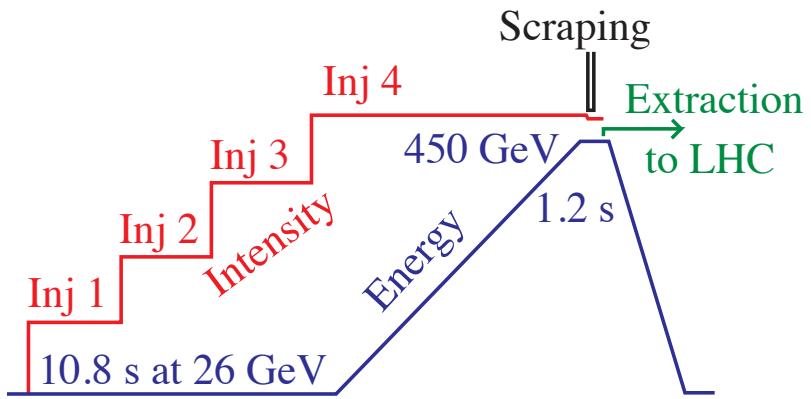
"Scraper Mechanics"



- Scraper jaws always move in this pattern
- Scraping, parking, out positions and timing adjustable

Scraping cycle and speed





schematic view when scraping is done in the SPS cycle

Time scale of scraping: < 40 ms

Fully operational and safe system requires : Scraper + BLM + fast beam abort - not yet there

Follow-up

The current (old ISR) scrapers have already been very useful for diagnostics and as MD-tool

- **45° scraper installation was staged - needs completion**
- **The present system was last successfully tested in MD in the SPS on the 5 Nov. 2008 and should be ok for 2009 - and a bit later for checks of the SPS beam quality**

Regular operation at full intensity for many years will require

- **follow up** (ATB, now EN / STI)

+

- **fast interlock with beam abort** (J. Wenninger et al. ?)

on the longer term

- **upgraded or new system, to full specs**

Follow-up

work / study requirements, for a new system or major upgrade
with input from prelim. discussion with Gianluigi Arduini and Roberto Losito :
ATB with OP, ABP, BI

- **Scraper :**

- Damage study (thermomechanical analysis)
- material optimization
- multicycling compatibility (motorization)
- instrumentation, BLM
- interlocks
- reliability study (motorization, vacuum, etc.)
- impedance aspects

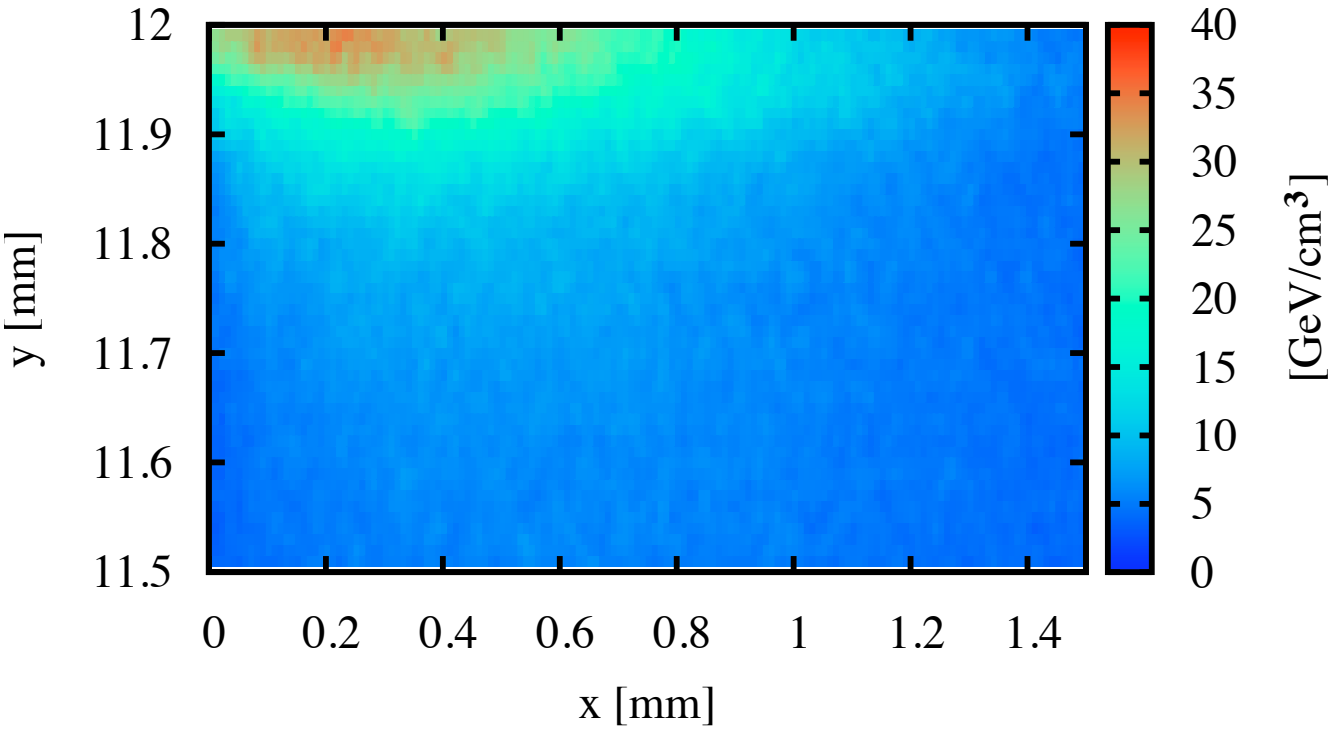
- **Collimators :**

- multicycling compatibility
- damage study
- material
- reliability study (motorization, vacuum, ..)
- interlocks
- impedance aspects

- **Study of momentum collimation**

Backup Slides

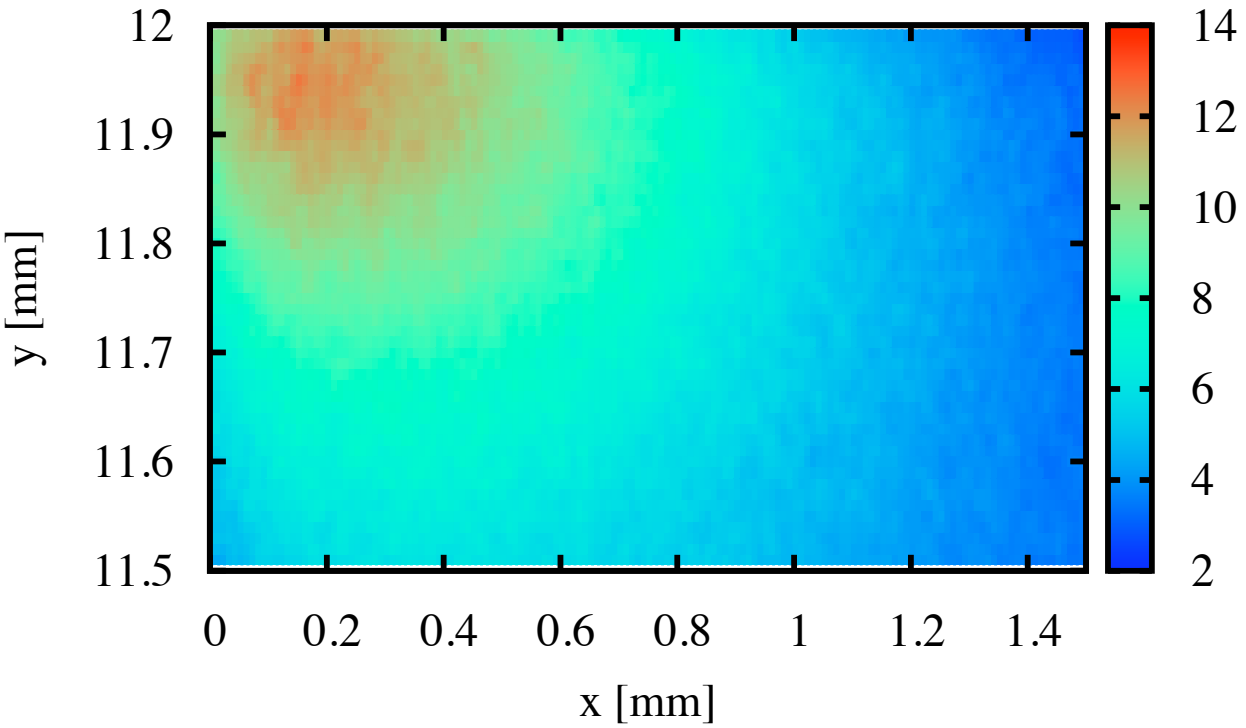
Accident scenario: Scrape 100% of beam



Melting at
$\approx 1\,\mathrm{GeV/cm^3}$

Full beam impact melts small part of scraper jaw.

Possible upgrade:
Faster, thinner scraper jaws



Current system:
30 mm active length
20 cm/s sweep

Simulated proposal:
10 mm active length
200 cm/s sweep

Gain a factor 3 in energy deposit density compared to current system!