Fluka Coupling for SPS Scrapers

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WP5 Tracking Workshop, CERN, 30th Oct 2015

Outline

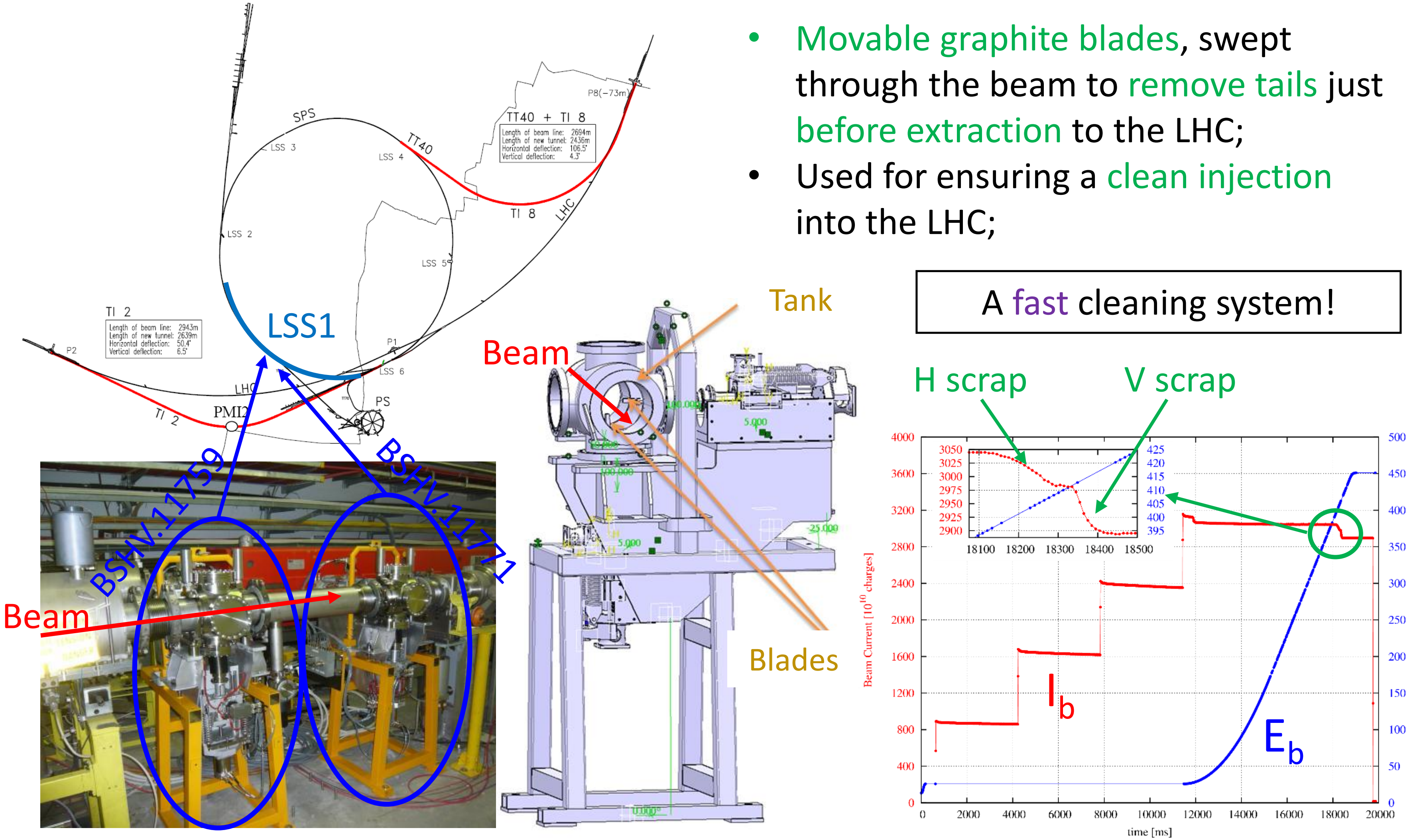
- Introduction
    - The SPS scrapers: what, why, where;
    - The upgrade proposal (LIU);
- Comparison between the two systems
    - To highlight main assets / liabilities;
- The burst test
    - To verify with beam high level of endep predicted by simulations (blade damage);
- Benchmark of simulation tool
    - BCT and BLM signals;

Introduction

The SPS Scrapers - *Present* Devices

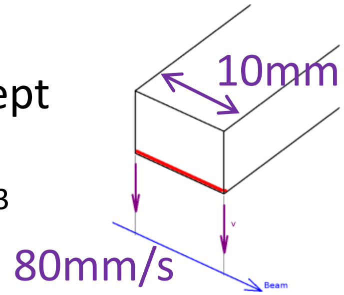
- Movable graphite blades, swept through the beam to remove tails just before extraction to the LHC;
- Used for ensuring a clean injection into the LHC;

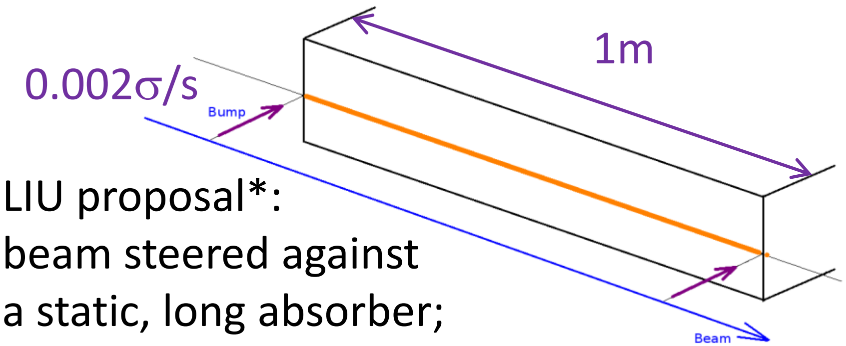
A fast cleaning system!



Upgrade: the *LIU* SPS Scrapers

Present system:
mechanical device swept
through the beam;
Graphite, 1.83 g/cm^3





LIU proposal*:
beam steered against
a static, long absorber;
Graphite, 1.67 g/cm^3

- Beam steering with magnetic bump:
  - more control on beam-impact conditions (endep + cleaning speed);
  - No mechanical movements → no wear;
  - More complex system;
- Longer absorber:
  - Higher prob. of inel. interaction per single passage → less passages per single proton (endep + cleaning speed);
  - Different endep regime (EM);
  - softer spectra of escaping particles

- Characterisation of both systems:
  - Endep in intercepting medium;
  - Evolution of beam intensity with time during scraping;
  - Losses around the ring;
- Explored parameters:
  - Present system: blade speed and material, scraping position, blade tilt, FT vs ramp;
  - LIU scrapers: bump speed, absorber length, tilt;

Not all covered here!
→ see Ph.D. thesis

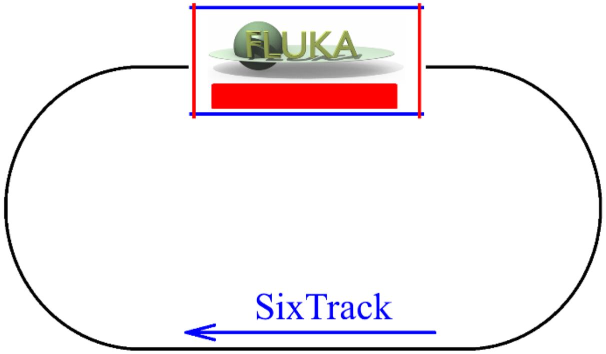
*O. Mete et al, "Feasibilty Studies in View of a New LIU-SPS Scraping System", CERN-ACC-NOTE-2013-0016

Comparison of Systems

Studies: Numerical Simulations

- Performance of the two systems evaluated by means of numerical simulations, as these are predictive tools, useful especially for design / optimisation;

- Multi-turn effects are important for cleaning systems on circular machines;
- Even more relevant for scrapers presently installed, esp. for evaluating endep:
  - Blades are scatterer extremely thin: graphite, 1 cm; → on average, 45 passages before undergoing a nuclear inelastic event;
  - Blades move: change in the distance between beam and blade with time;



Beam-absorber relative distance changes over time; → simulation in a "continuous" way requires on-line endep and aperture check!

- Take advantage of:
  - Models of particle-matter interaction in Fluka;
  - Description of single particle beam dynamics in synchrotrons in SixTrack;
- In the following:
  - Quick insight into main results (no time to go through!! e.g. BLM threshold for protecting blades against damage);
  - Few, meaningful technical details;

Energy Deposition

Scenario: 0σ scraping, i.e. the whole beam is scraped away, incl. core, not only tails;
→ Somehow extreme, but the worst one we can think of;

Tech: bump rising simulated with embryonic DYNK module

Proceedings of IPAC2013, Shanghai, China WEPEA064

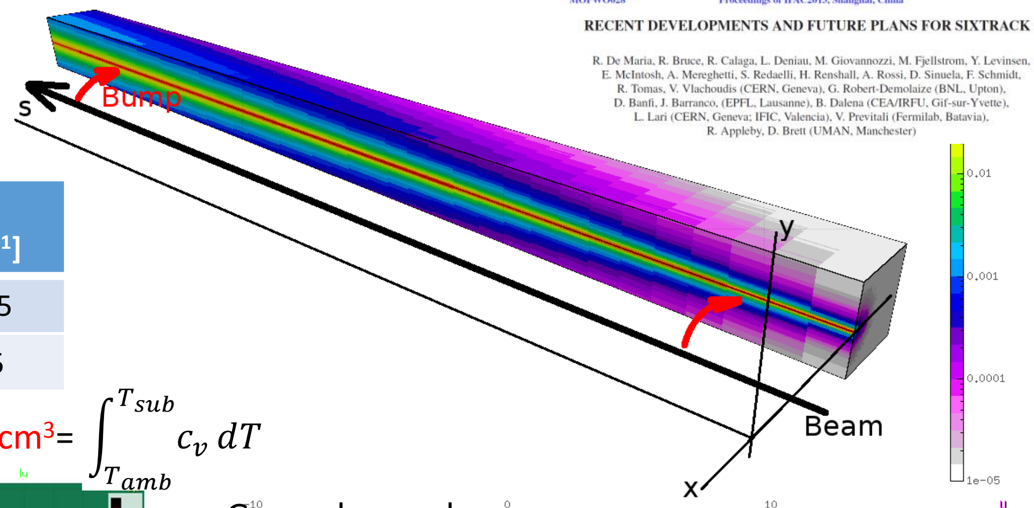
SIXTRACK-FLUKA ACTIVE COUPLING FOR THE UPGRADE OF THE SPS SCRAPERS

A. Mereghetti*, CERN, Geneva, Switzerland, and UMAN, Manchester, UK, F. Cerutti, R. De Maria, B. Goddard, V. Kain, M. Meddahi, O. Mete, Y. Papaphilippou, D. Sinuela Pastor, V. Vlachoudis, CERN, Geneva, Switzerland R. B. Appleby, UMAN, Manchester, UK

MOPWO028 Proceedings of IPAC2013, Shanghai, China

RECENT DEVELOPMENTS AND FUTURE PLANS FOR SIXTRACK*

R. De Maria, R. Bruce, R. Calaga, L. Deniau, M. Giovannozzi, M. Fjellstrom, Y. Levinsen, E. McIntosh, A. Mereghetti, S. Redaelli, H. Renshall, A. Rossi, D. Sinuela, F. Schmidt, R. Tomas, V. Vlachoudis (CERN, Geneva), G. Robert-Demolaize (BNL, Upton), D. Banfi, J. Barranco, (EPFL, Lausanne), B. Dalena (CEA/IRFU, Gif-sur-Yvette), L. Lari (CERN, Geneva; IFIC, Valencia), V. Previtali (Fermilab, Batavia), R. Appleby, D. Brett (UMAN, Manchester)

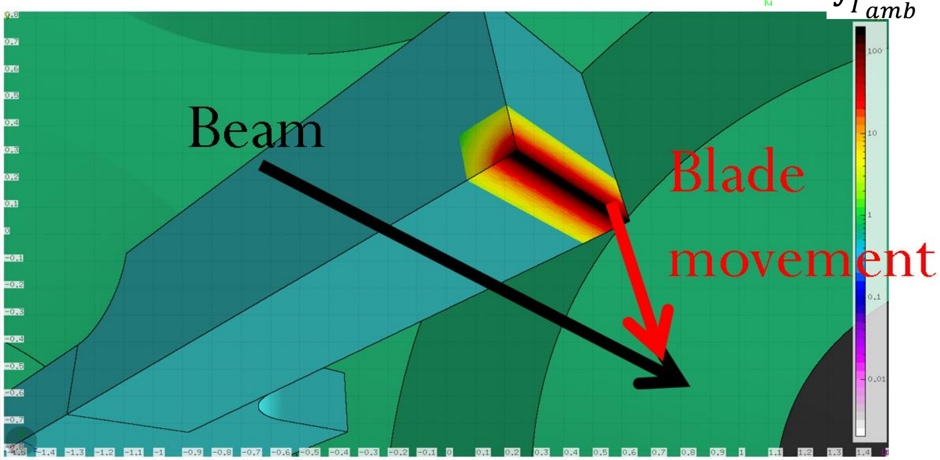


Gaussian beams, 288b

Scraper	ε_N [μm]	σ_δ [10^{-4}]	E_{max} [GeV/cm^3]	N_p [10^{11}]
Present	1	1	30-35	1.15
LIU	2.5	5.25	10-11	2.5

16-17 GeV/cm^3 @ ε_N = 1 μm

>> 12.8 kJ/cm^3= $\int_{T_{amb}}^{T_{sub}} c_v \, dT$



Tech: moving bodies in Fluka

General remarks:

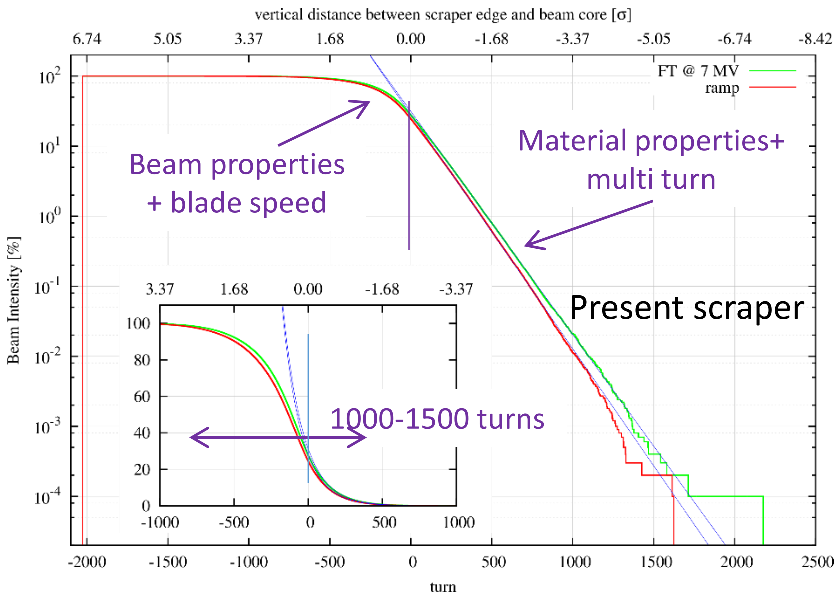
- endep collapsed on very first layers of material – cleaning plane;
- non-cleaning plane: endep keeps memory of beam size → dependence on σ;
- Speed: relevant for present scrapers; less important for LIU ones;
- Tilt: relevant for both → no knob in case of present system;
- Longer medium can help;

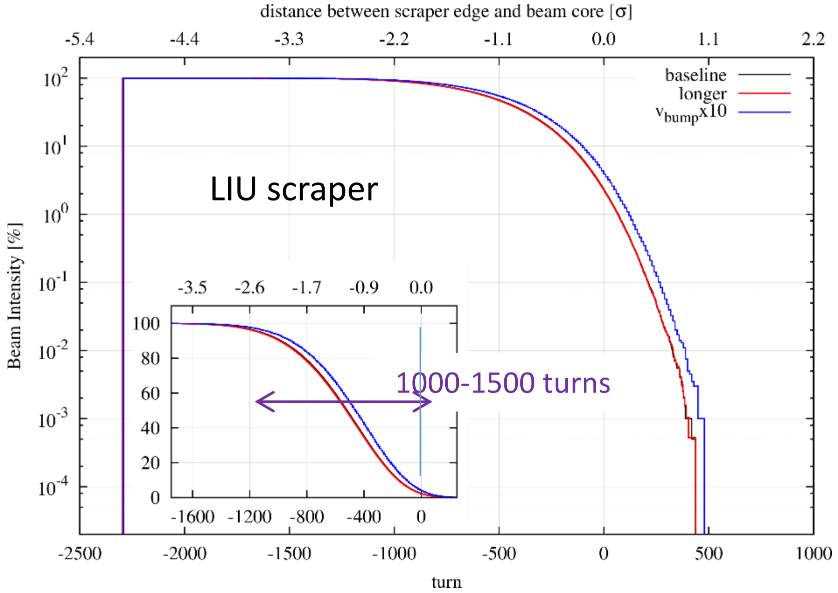
Not covered here!
→ see Ph.D. thesis

Beam Intensity vs Time

Present scraper
- Dependence on blade properties: material, length and speed (not linear);
- No big dependence on tilt angle but for one particular case (see benchmark);

Tech: permanent mag. bump in LSS1 + double Gaussian distribution + ramping (in 1 simulation), starting from 393 GeV;



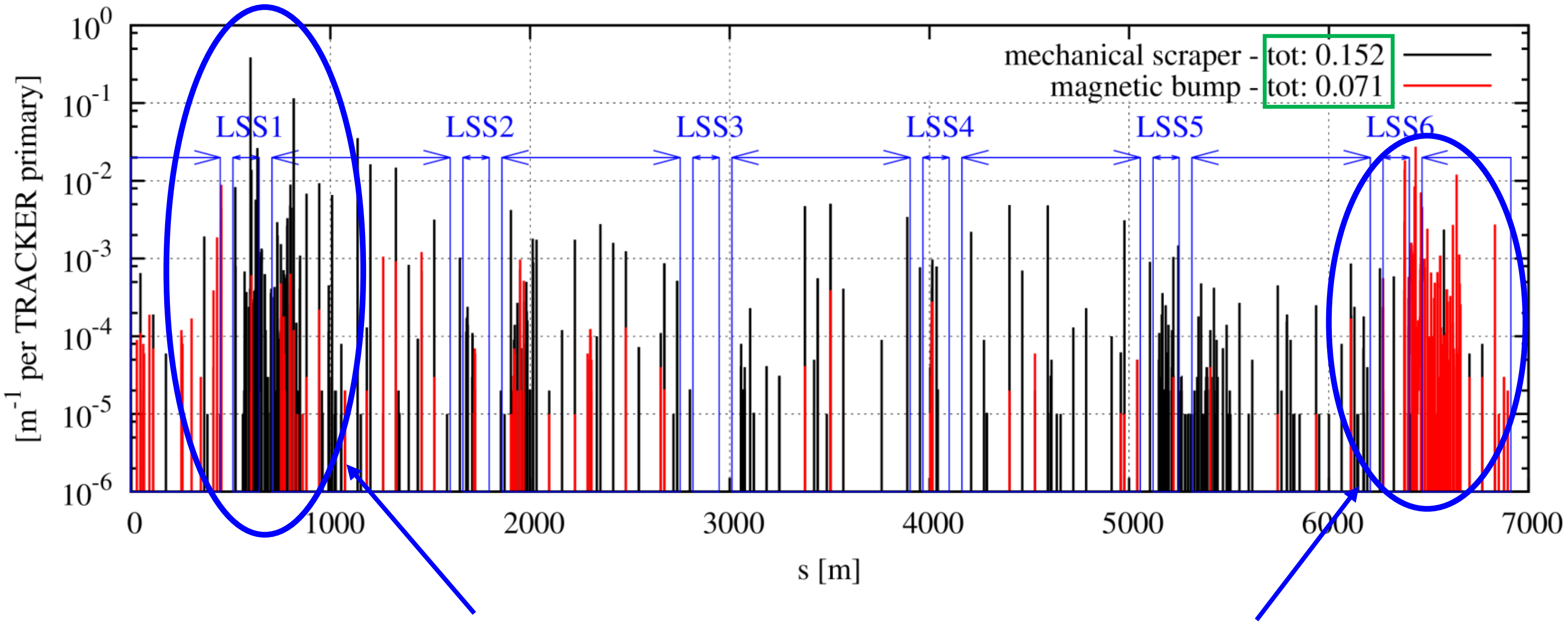


LIU scraper
- Almost linear dependence on speed of rising the bump up (long absorber, high prob. of inel. inter.);
- No big dependence on tilt angle;
- No relevant improvement in deploying an even longer absorber;

Loss Maps

H systems, cut at 440 GeV/c (δ =~2%)

Net gain: factor 2



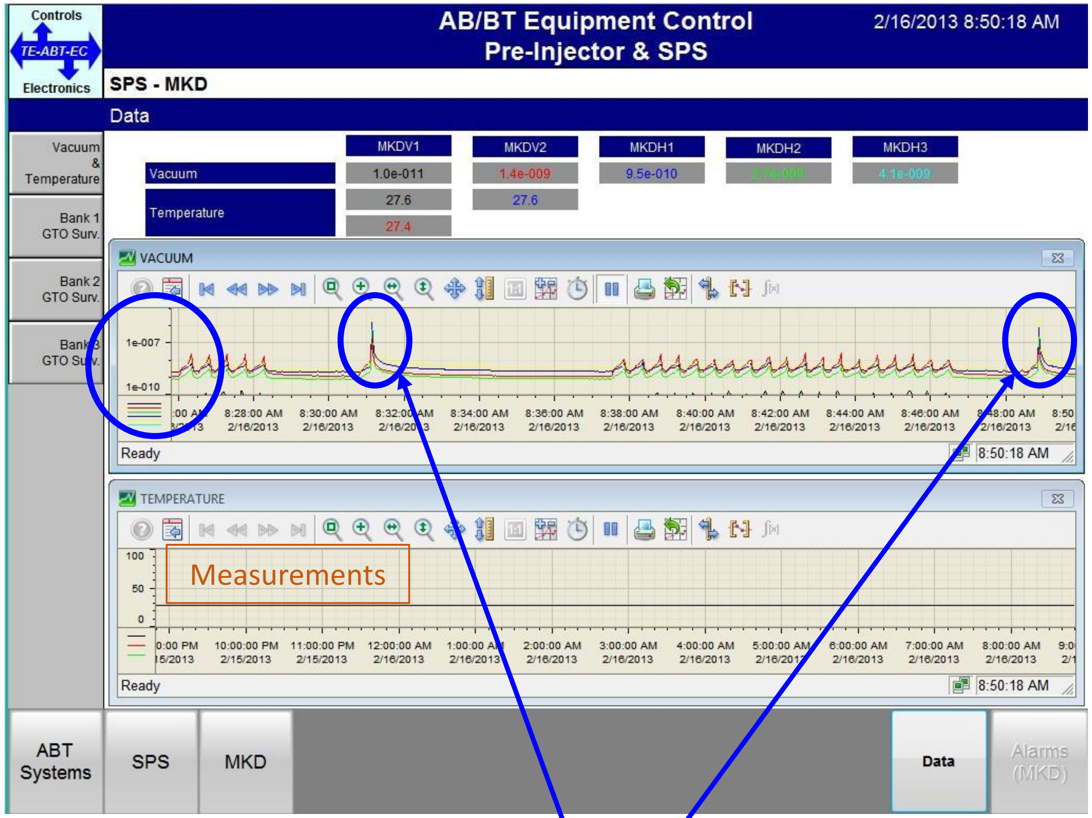
Losses mainly localized locally at absorber and in downstream DS/arc

Tech: online aperture check

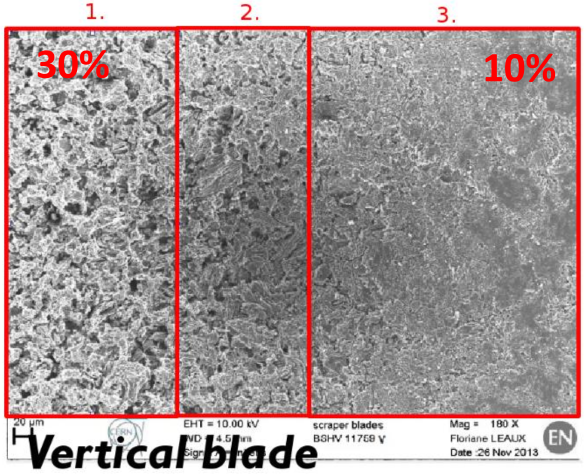
The Burst Test

The Burst Test (16th Feb 2013)

Aim: to verify with beam the high values of endep in the blade predicted by simulations
→let's scrape away the whole SPS beam, i.e. 288b, 1.15 10^{11} p/b;



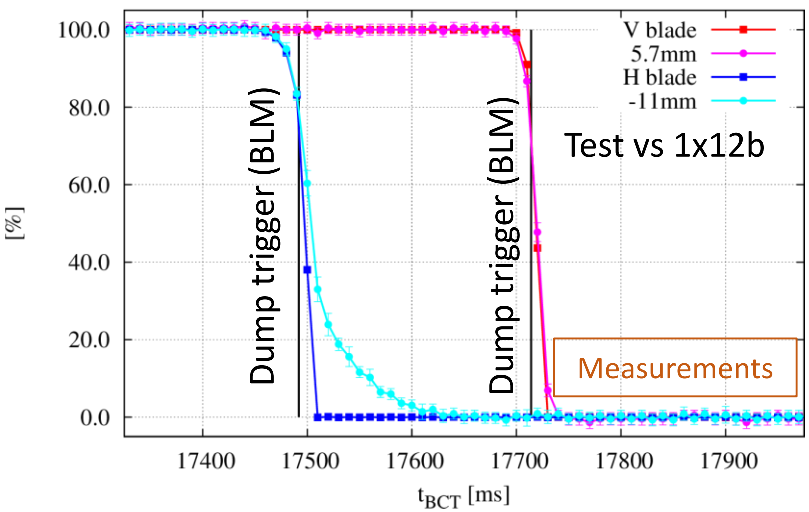
Vacuum spikes (>3oom) at test of blades, signs of induced damage



Change in porosity
(F. Leaux, EDMS 1339153)

Premature Dump During Test and Estimation of Endep

From BCTs



dump trigger (BLM) retrieved from Timber:

SPS → kickers → beam dump → MKD.117:TRIGGER_CYCLE_TIME

Comparing with BCT signal: > 12.8 kJ/cm^3

- H blade: ~20% scraped -> 20-24 kJ cm^{-3};
- V blade: ~30% scraped -> 27-37 kJ cm^{-3};

Confirmed: amount of beam scraped leads to local sublimation (vacuum spikes);

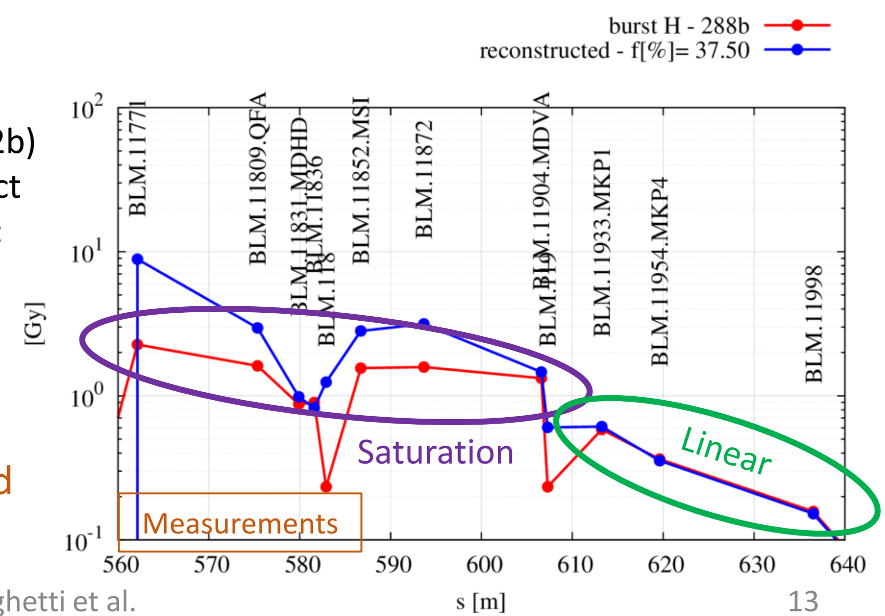
From BLMs

- combination of signals at **full** beam scraping (1x12b) and from dump of **full** beam (4x72b), to reconstruct the BLM pattern that should have been measured:

$$R_{i,k} = sR_{i,scrp} + (1 - s)R_{i,dump}$$

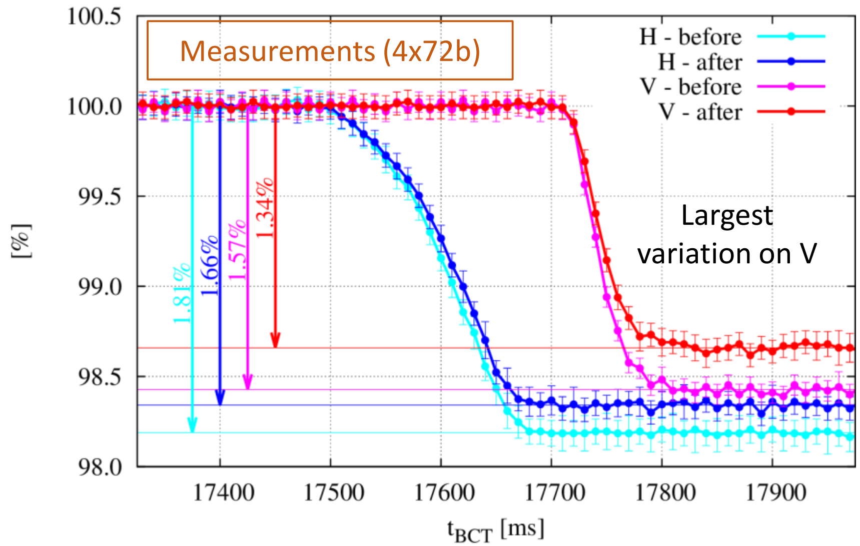
- H blade: s=38% scraped -> 37-46 kJ cm^{-3};
- V blade: s=44% scraped -> 38-53 kJ cm^{-3};

Confirmed: only a fraction of beam was scraped (premature dump);



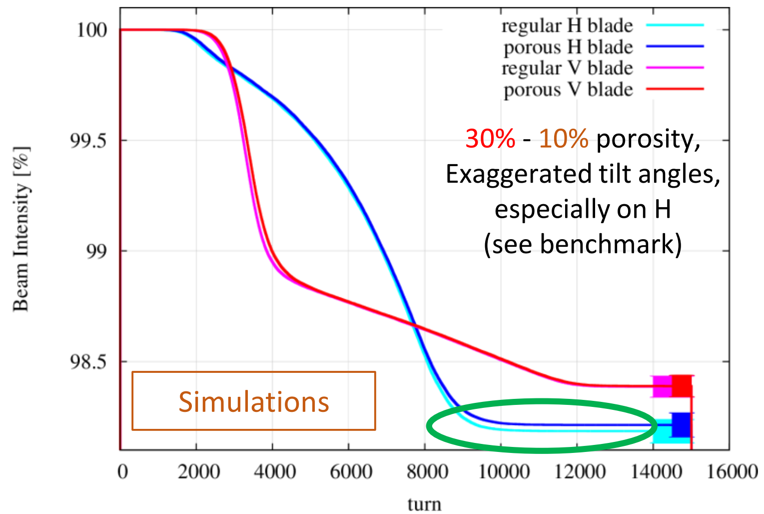
Did We Affect the Performance?

Regular scraping (i.e. at 3σ/4σ) performed **before** (light colors) and **after** test (dark colors), to spot possible loss of performance

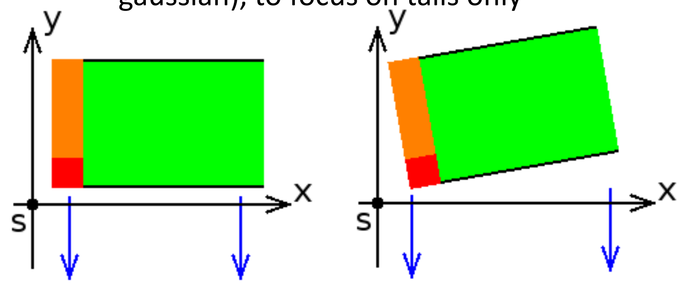


Apparent loss of performance must be due to change in beam profile / emittance, or a drift in close orbit;

Change in fraction of surviving population too small wrt measurements;



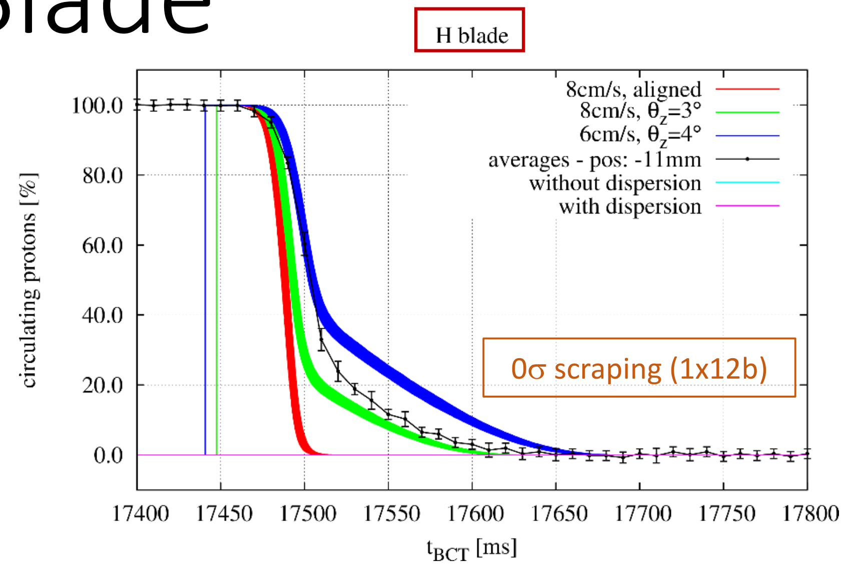
Tech: biased beam distribution (double gaussian), to focus on tails only

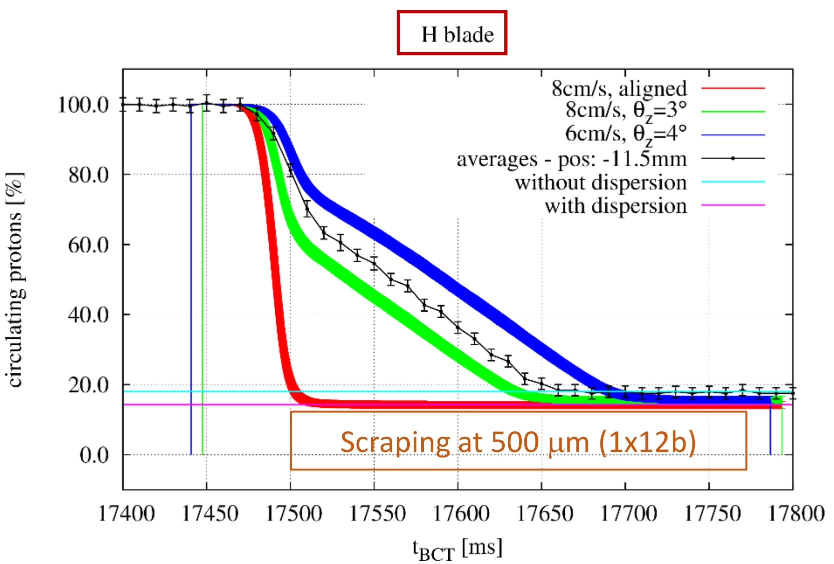


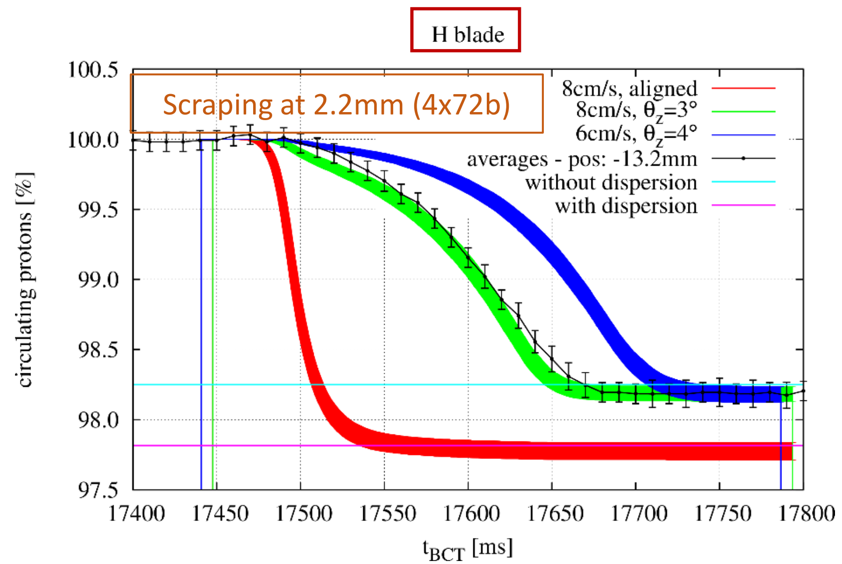
The Benchmark

BCT Signals – H Blade

- Benchmark against time evolution of beam intensity during scraping, to get actual speed and tilt angle of blade;
  - **H**: 6-8 cm/s, 3-4°;
  - **V**: <6 cm/s, <0.5°;
- Several scraping positions tested, used also to diagnose the beam distribution;

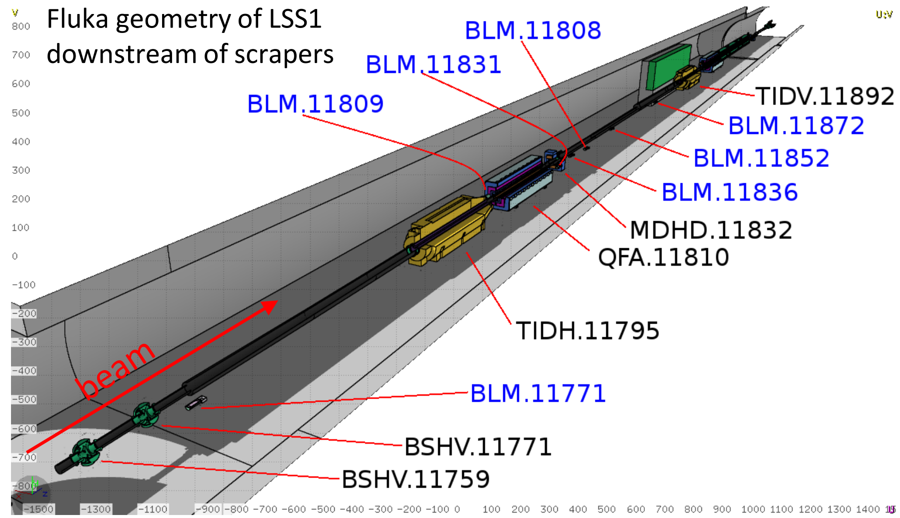


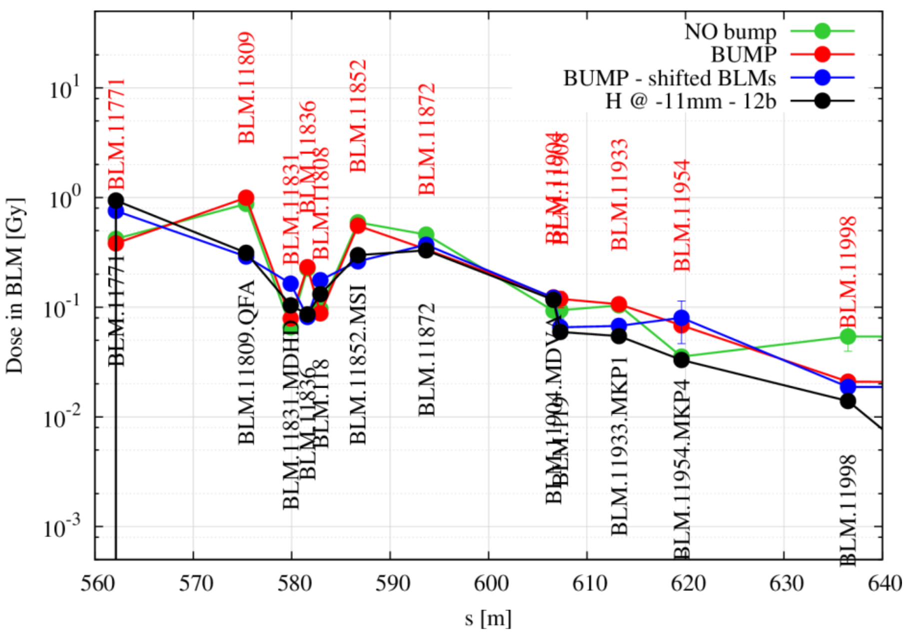


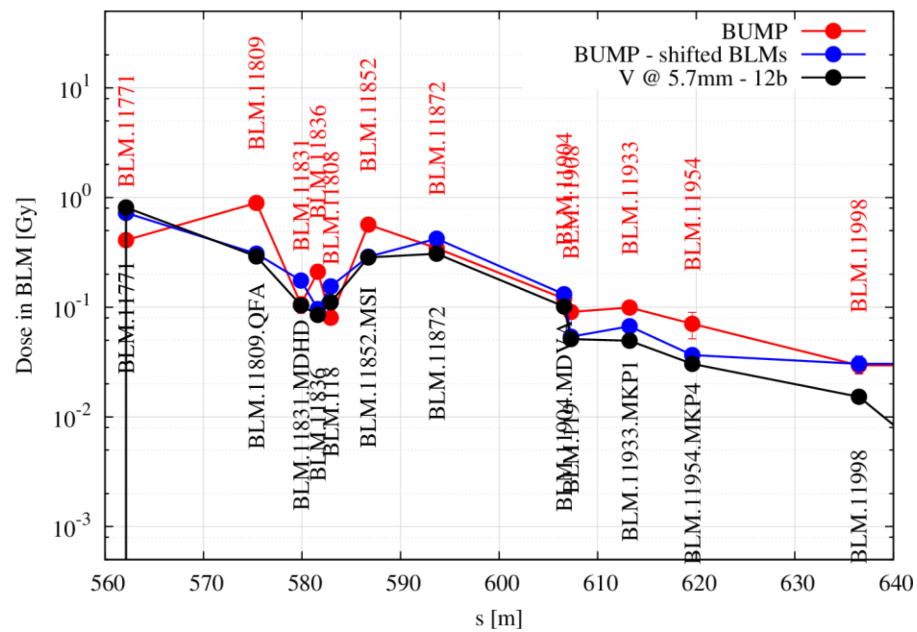


BLM Signals

- Fluka-SixTrack coupled simulations with full geometry of LSS1 downstream of scrapers (incl. magnets);
- Benchmark against BLMs in absolute values – 1st with SPS ones;
- Simulation results dramatically dependent on BLM positions – some discrepancies between technical drawings;





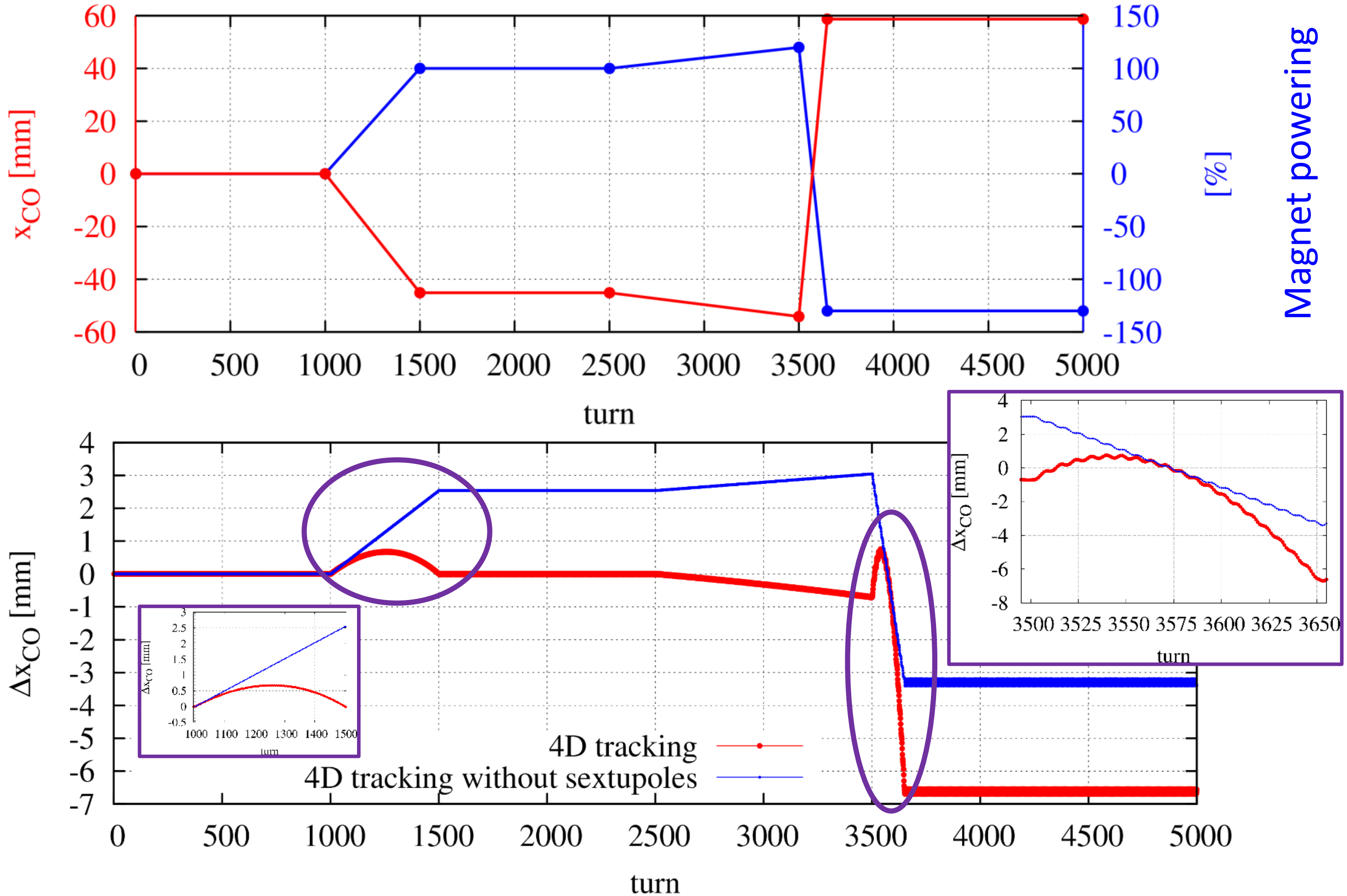


Conclusions

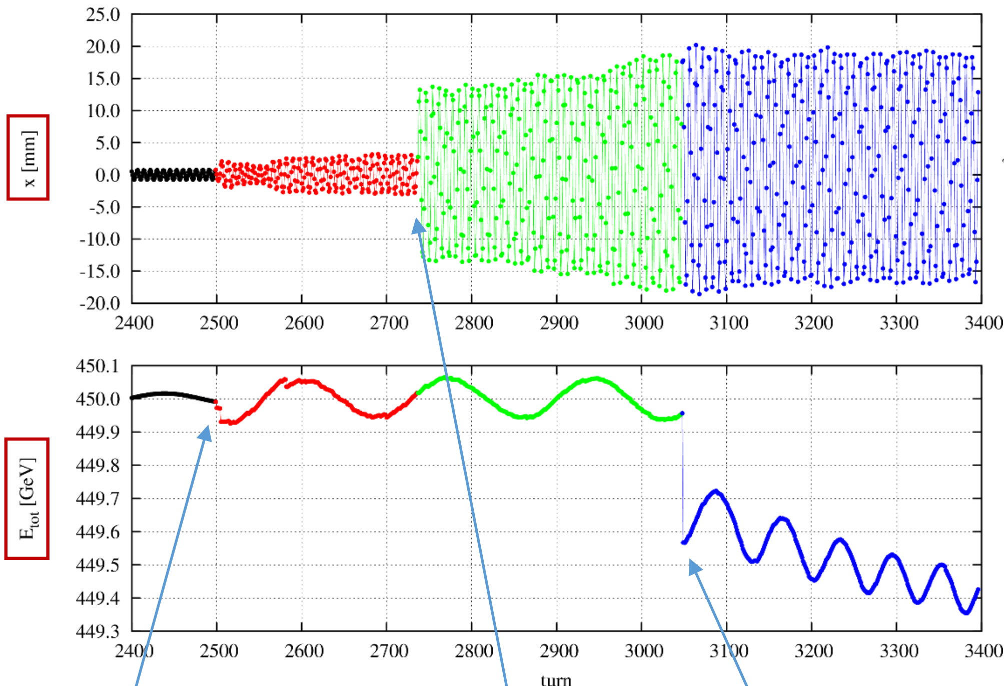
- Scrapers are installed in the SPS to provide the LHC with a clean injection;
  - Fast system, made of movable blades swept through the beam;
- LIU project: proposal of upgrade, for improving performances;
  - Made of a static absorber block against which the beam is steered for scraping;
- Comparison of performance of the two systems;
  - By means of numerical simulations - Fluka-SixTrack coupling;
  - Based on 0 σ scraping:
    - Worst scenario in terms of endep;
    - Regular, operational scraping involves only tails;
    - Diagnostics tool: lower beam intensities;
  - Characterisation: endep in absorbing medium, evolution of beam intensity with time, losses induced around the ring;
- A burst test was carried out to verify damage levels in blade of present system – signs of damage found;
- Benchmark of simulation tool against BCT readouts during scraping (blade speed/tilt) and BLM signals in LSS1 (absolute values);

Spare Slides

Checking DYNK



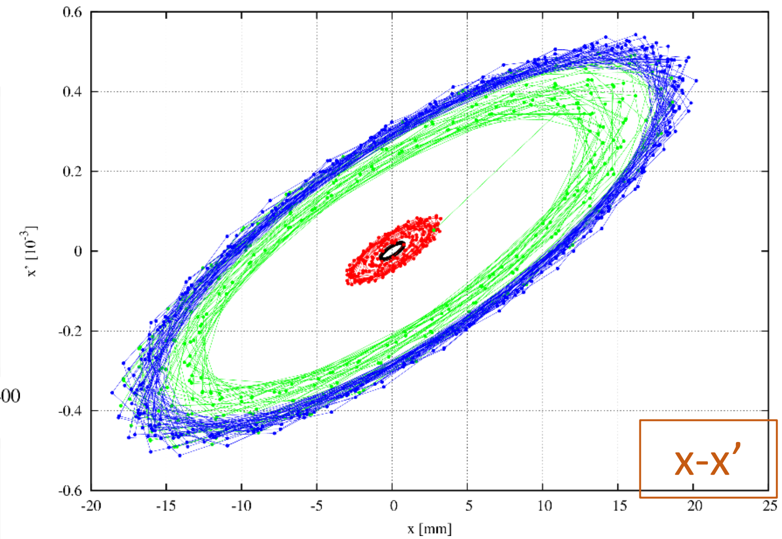
Checking the Fluka-SixTrack Coupling

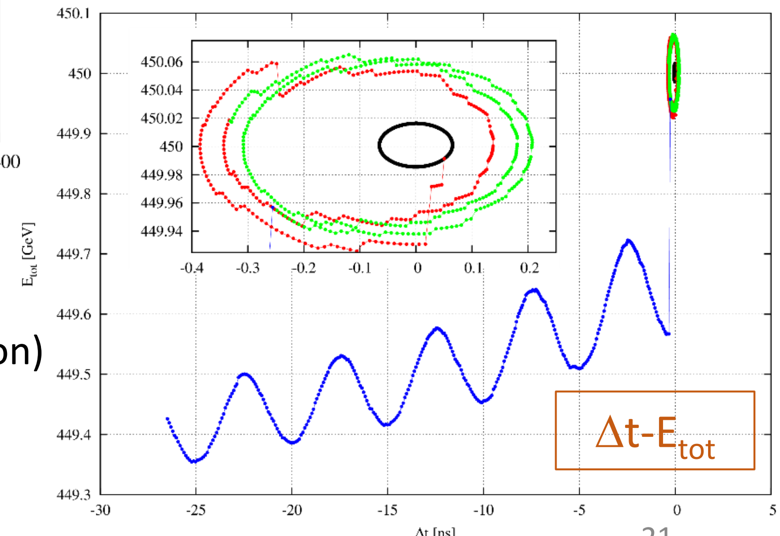


Two consecutive nuclear elastic events (one per turn)

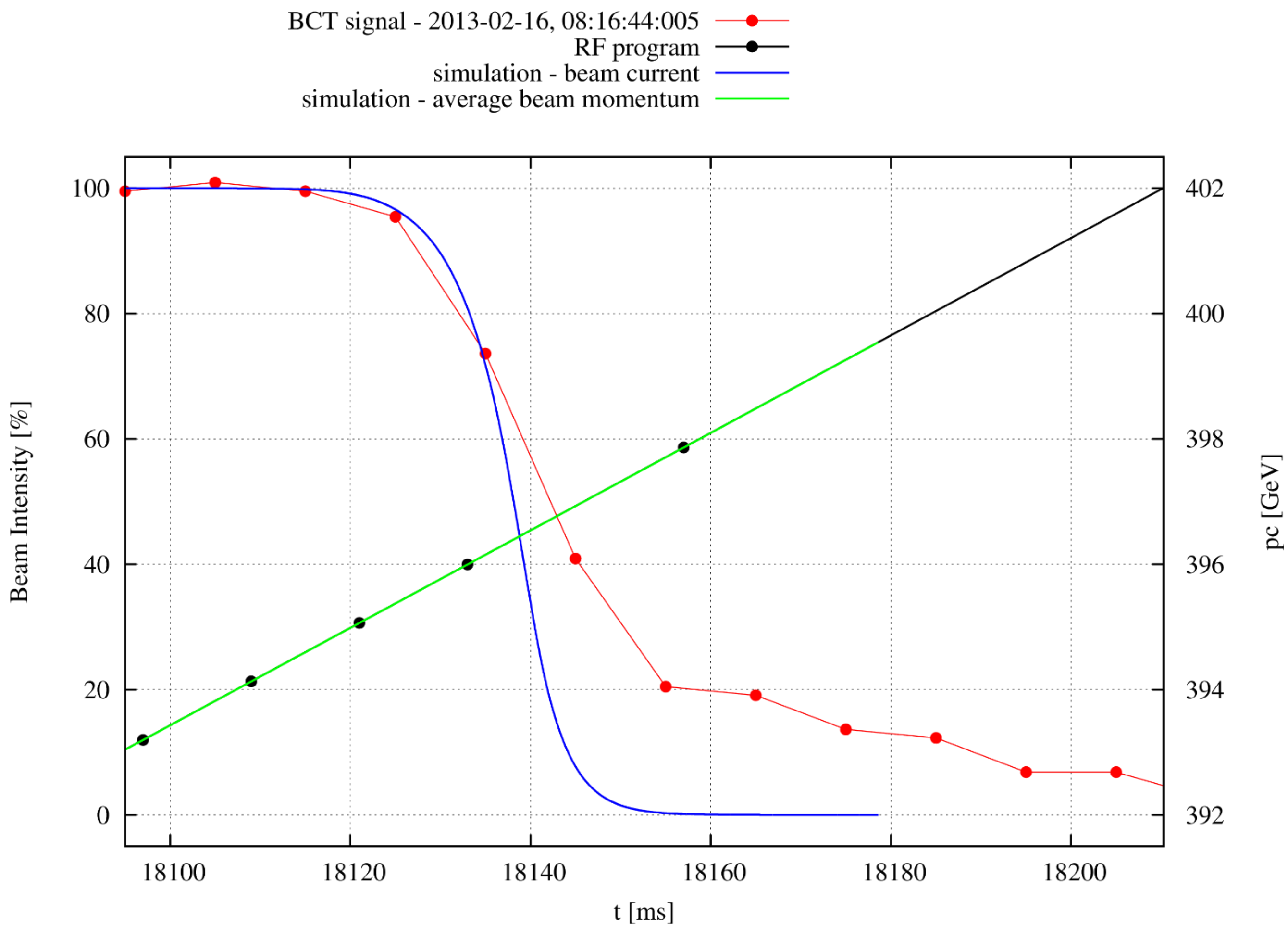
Rutherford scattering

Ionisation (hard knock-on)





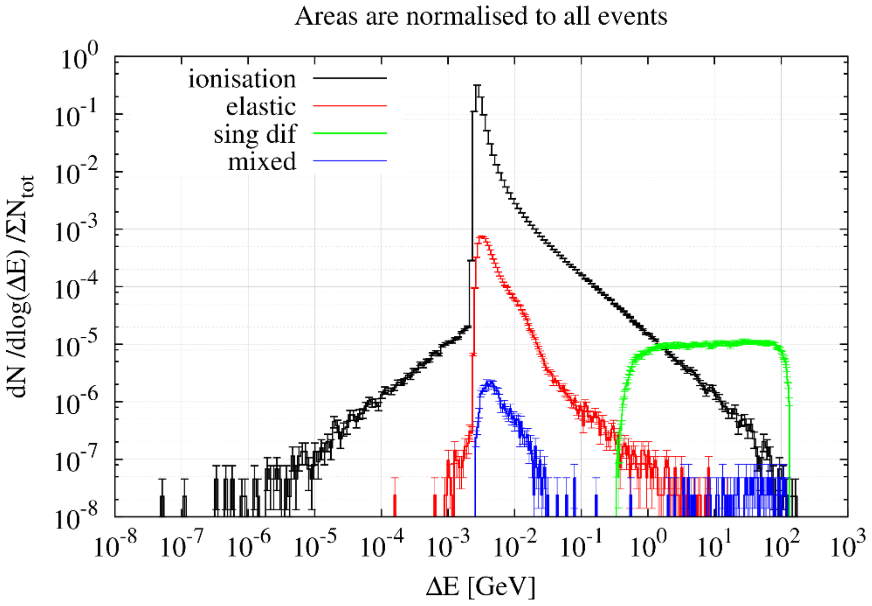
Checking SixTrack Tracking with Acceleration



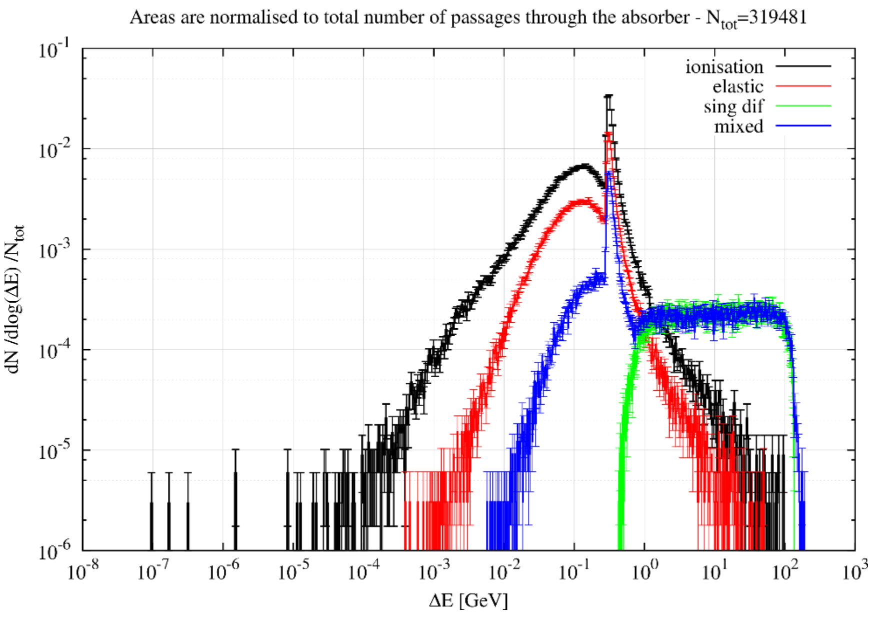
Single Scattering Events

Comparison of H systems

Present system



Upgraded system

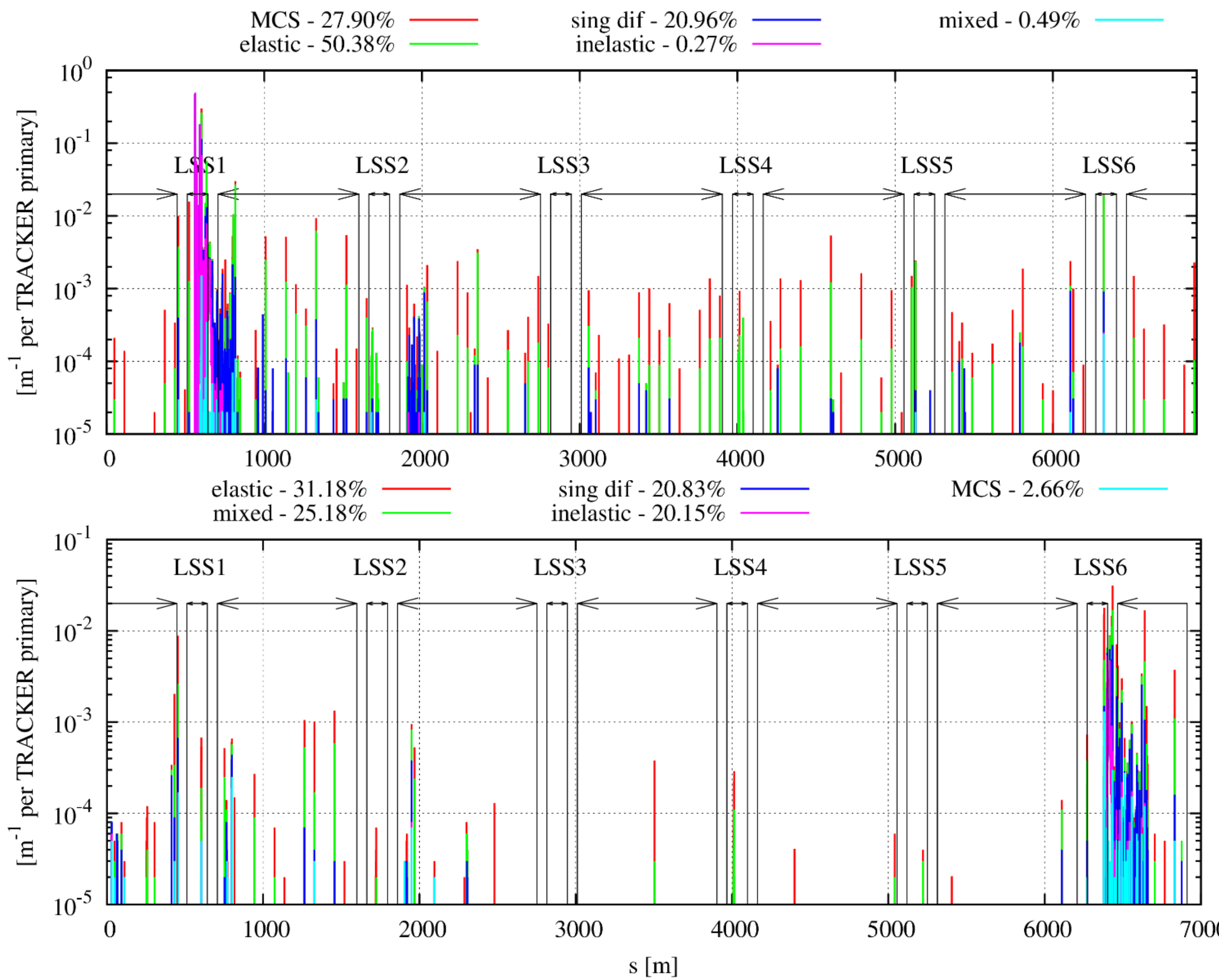


Losses and Last Scattering Event

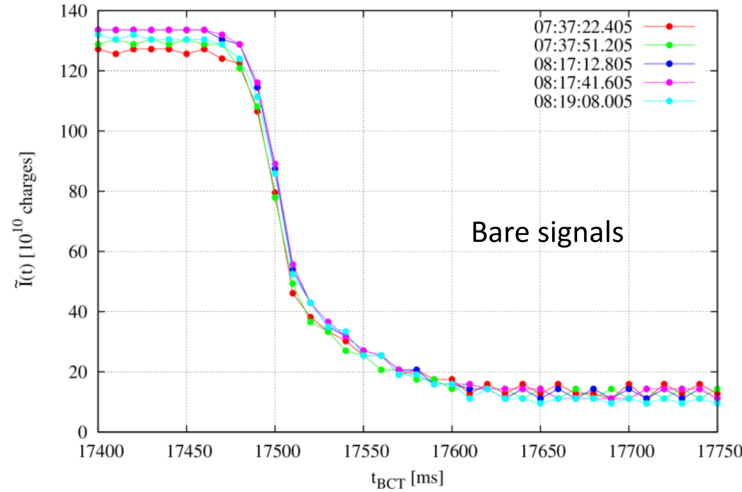
Comparison of H systems

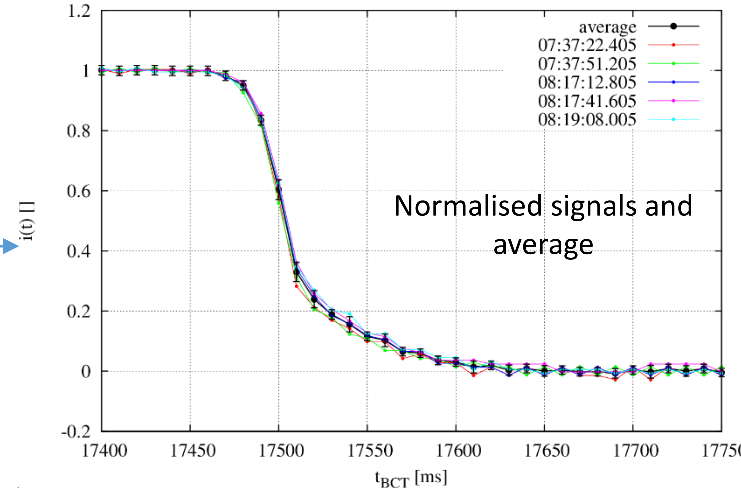
Present system

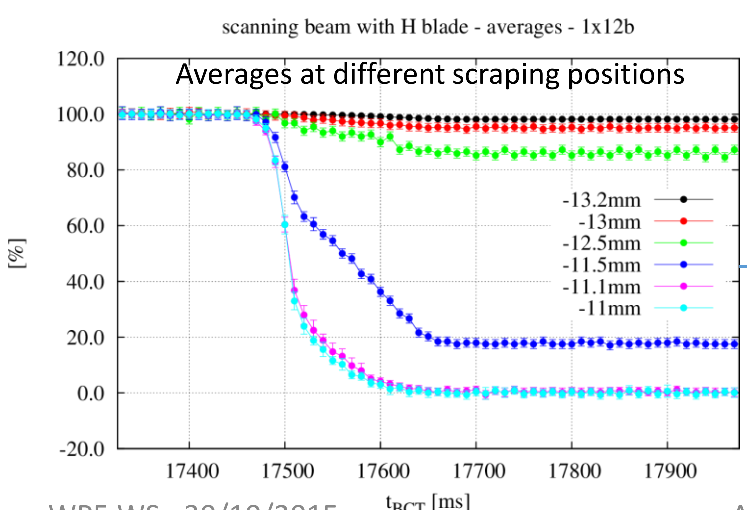
Upgraded system

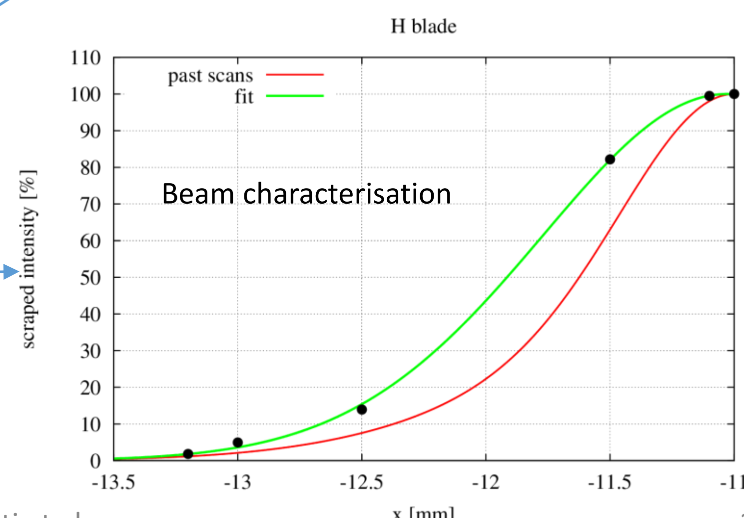


BCT Signals and Beam Characterisation

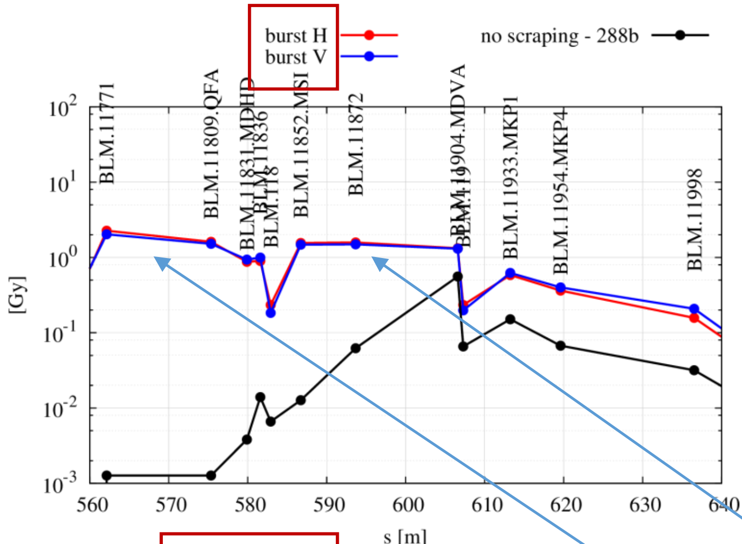


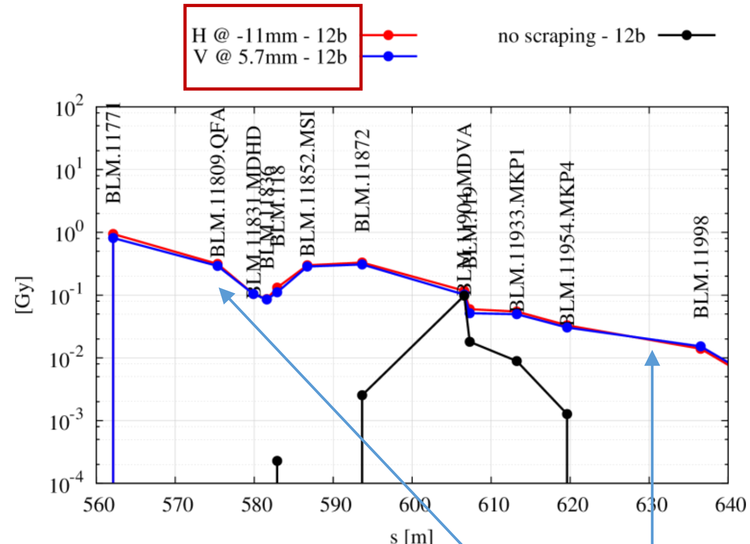


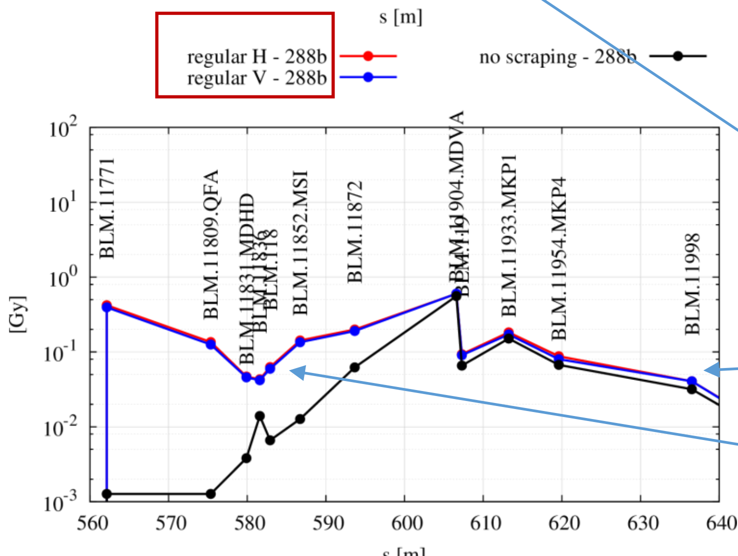




Playing with BLM Signals







Real scraping pattern (0σ scraping)

Saturated scraping pattern (0σ scraping)

Little contribution from scraping pattern on top of dump signal

Real scraping pattern (regular scraping)

BCT Signals – V Blade

- Benchmark against time evolution of beam intensity during scraping, to get actual speed and tilt angle of blade;
    - **H**: 6-8 cm/s, 3-4°;
    - **V**: <6 cm/s, <0.5°;
- Several scraping positions tested, used also to diagnose the beam distribution;