Extraction Studies with CNGS Beam

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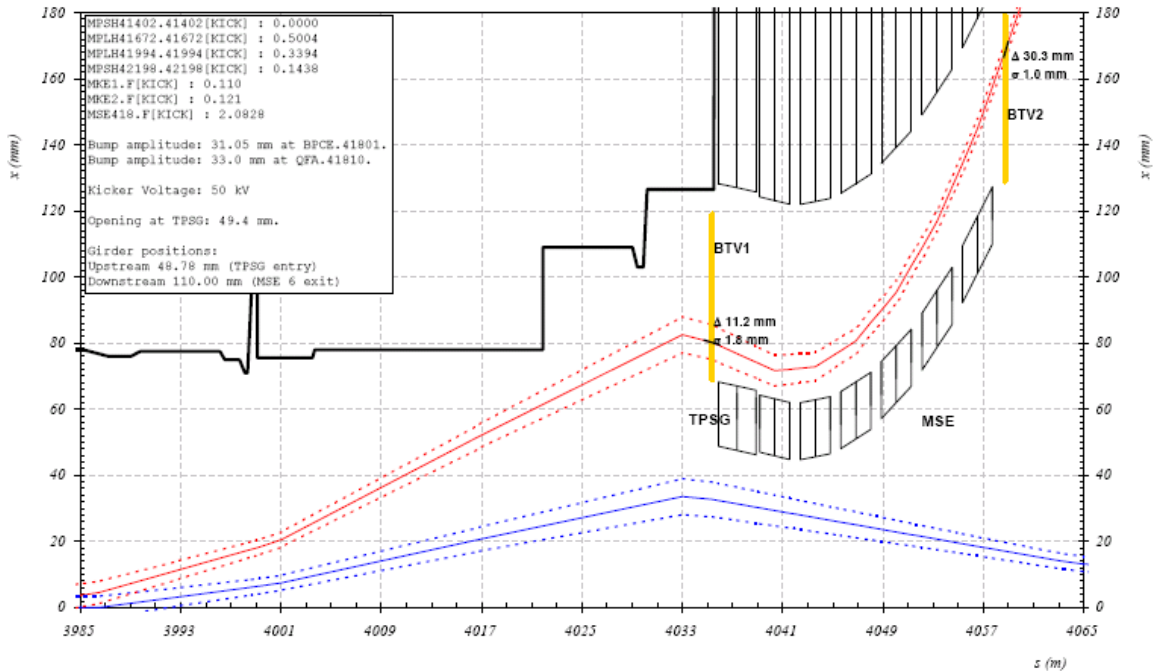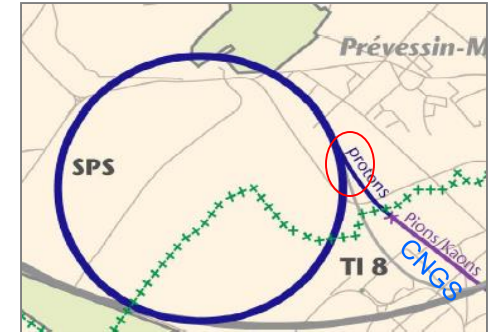
- Machine Protection

- Summary

Extract **2 x 10.5 μs long SPS batches**, nominally **2.4e+13 protons** per batch at 400 GeV
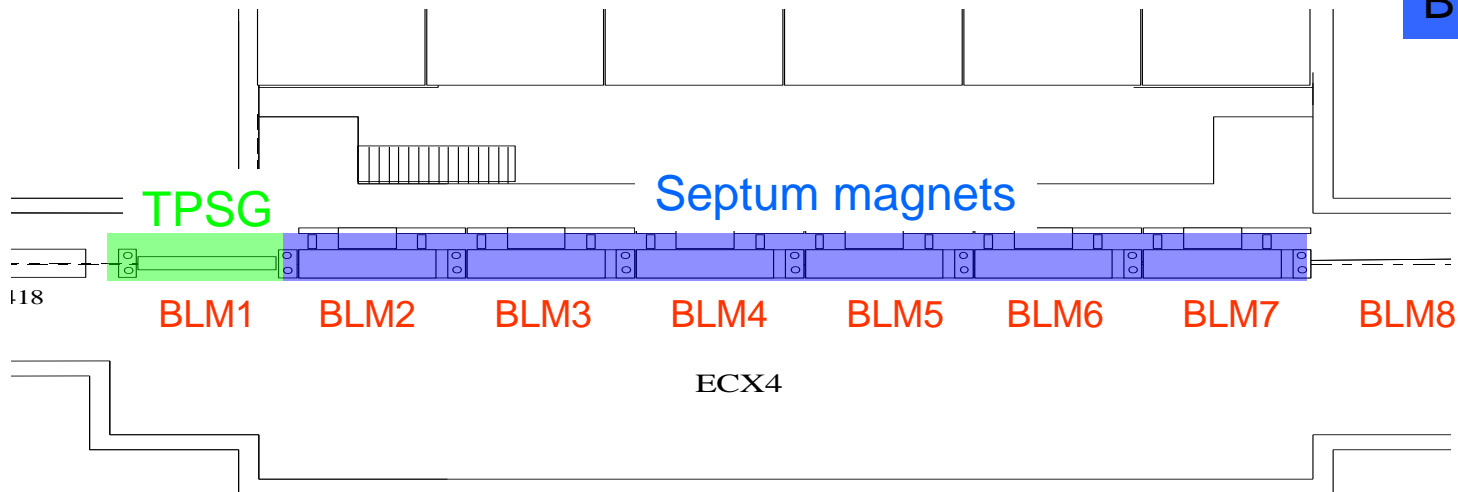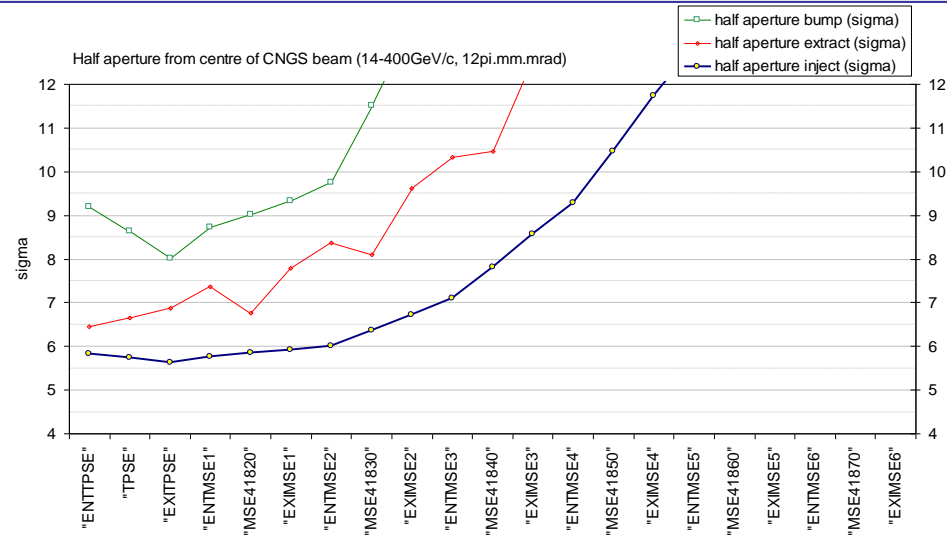
EQUIPMENT:

- 5 extraction kicker magnets (**MKE**):
  - rise time: 1 μs, kick length: 11.3/12.1 μs, voltage: 50 kV

- 6 septum magnets (**MSE**)

- **TPSG** – protection element for MSE

- 4 extraction bumper magnets:
  - 31.5 mm **extraction bump**

- **enlarged aperture** quadrupole magnets

- instrumentation

Constraints (1)

- **Aperture for circulating bumped beam**

  – design: 9.3 σ

- **Aperture for TPSG/MSE for extracted beam**

  – design: 6.5 σ

- **Losses during extraction**

  – below 0.1 % of nominal (radiation)

Half aperture from centre of CNGS beam (14-400GeV/c, 12pi.mm.mrad)

- half aperture bump (sigma)
- half aperture extract (sigma)
- half aperture inject (sigma)

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TPSG

Septum magnets

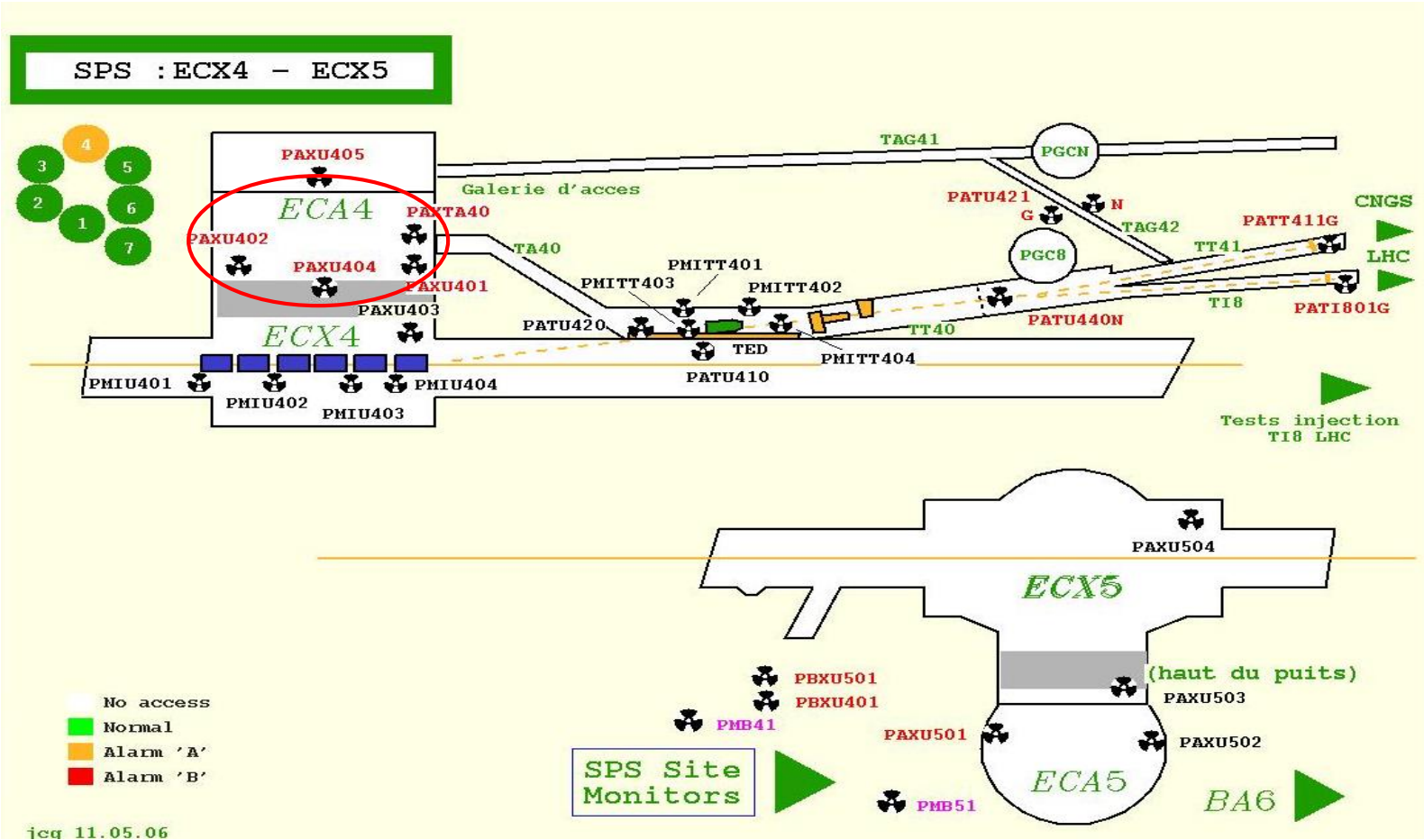BLM1   BLM2   BLM3   BLM4   BLM5   BLM6   BLM7   BLM8

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ECX4

Constraints (2)

- Radiation limits in ECA4 (**<u>free access</u>** during beam operation):
 - 5 µSv/h (corresponds to beam loss on TPSG of about 0.1% of nominal)

Measured Beam Loss Profiles on BLM1 – BLM8

- Measurements with low intensity:
  - Intensities ~ 3e+11 – 2e+12
  - Beam loss per proton from circulating beam 1)
    - via increasing bump amplitude
  - Beam loss per proton from extracted beam 2)
    - via decreasing kicker voltage

- Outcome:
  - Beam loss on the inside of the TPSG leads to higher beam loss signals.

- Normal operation loss: most likely **swept beam**
  - Combination of 1) and 2)
  - Beam loss profile combination of 1) and 2)

Beam loss per 10^10 protons for extracted and circulating beam
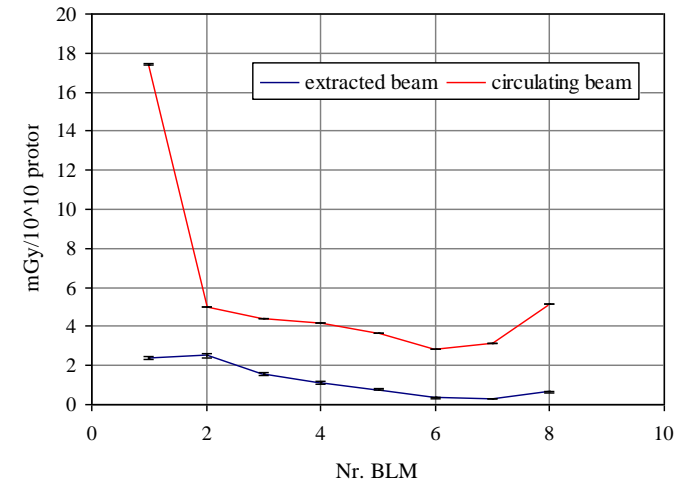
Comparison of loss patterns
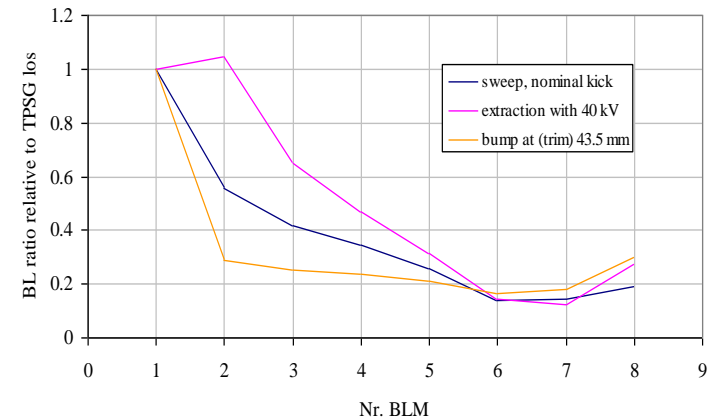
Calibration – Measurement Results during CNGS Commissioning (2)

Aperture Measurement

- **Result for circulating beam (increasing bump):**
  - TPSG edge ~13 mm from beam center
  - ~ 8.3 nominal sigma (design: 9.3 sigma)

- **Result for extracted beam (decreasing kicker voltage):**
  - TPSG edge ~ 10.6 mm from beam center
  - ~ 6.8 nominal sigma (design: 6.5 sigma)

- **Apertures are OK**

Relative losses at TPSG vs. beam position

Kicker voltage vs. beam loss at TPSG
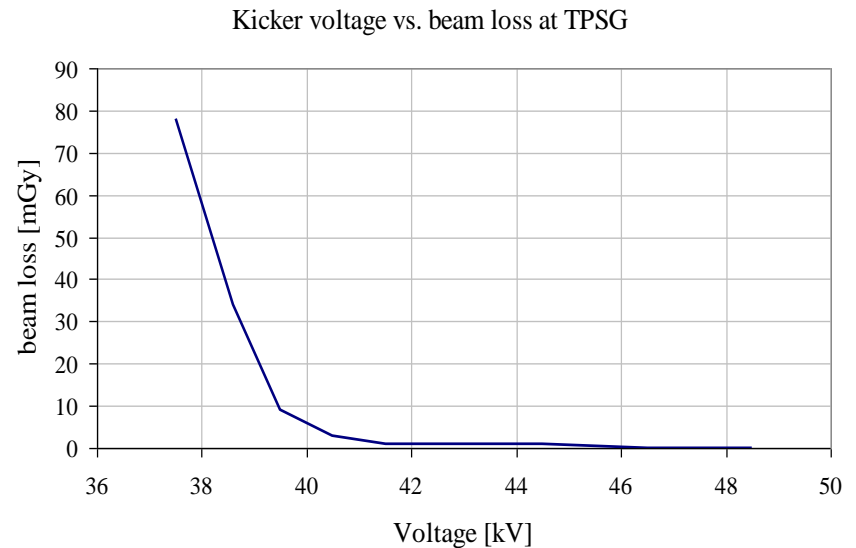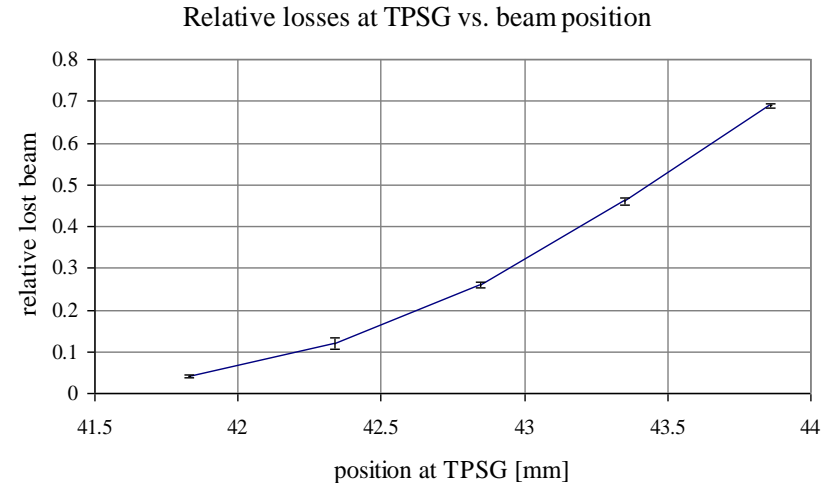
Calibration – Measurement Results during CNGS Commissioning (3)

Radiation in ECA4:

First comparison between simulation and measurements for a loss of 1.26e+11 protons @ 400 GeV/c on TPSG

	Latest calculation prediction	Measurement
Top of shielding	~ 1230 nSv	~ 700 nSv
Barracks	~ 30 nSv	~ 20 - 27 nSv
ECA4 floor (entrance TT40)	~ 30 nSv	~ 14 - 20 nSv

Possible explanations of difference between simulation and measurement:

- real wall thickness 4.8m – 5m , simulated wall thickness: 4.8m (conservative approach)

- new wall (40 cm) at "ECA4 maze exit" not considered in calculation

- detectors are calibrated to AmBe source

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- Nominal losses are between:

  - 0.05 % …scaled with circulating beam loss pattern

  - 0.39 % ... scaled with extracted loss beam pattern

- Extraction related losses stem "only" from beam in gap

  - gap cleaned with first extraction (during fall and rise time of kicker)

  - no losses on second extraction

Comparison of Loss Patterns
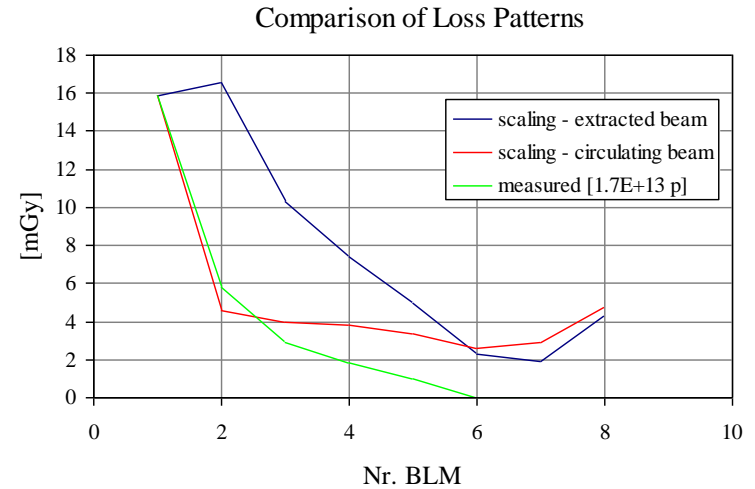
Beam loss on TPSG over 9 h operation (~1.7e+13 protons per extraction)
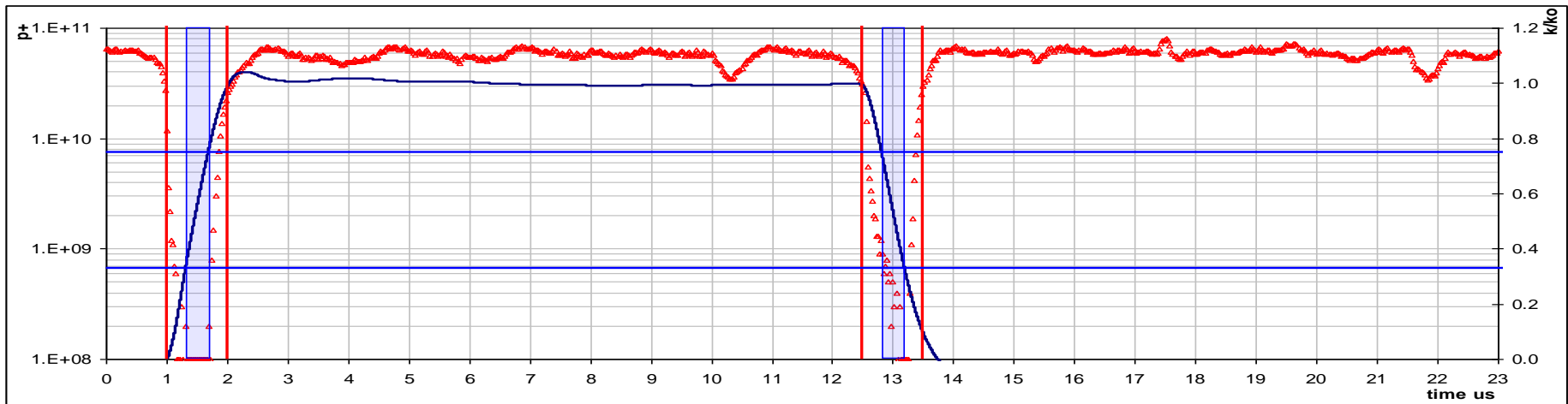
Radiation in ECA4:

Detector readings during CNGS Opera run

Top of the shielding

Barracks

Floor

PAXU404 uSv   PAXU405 uSv   PAXTA40 uSv
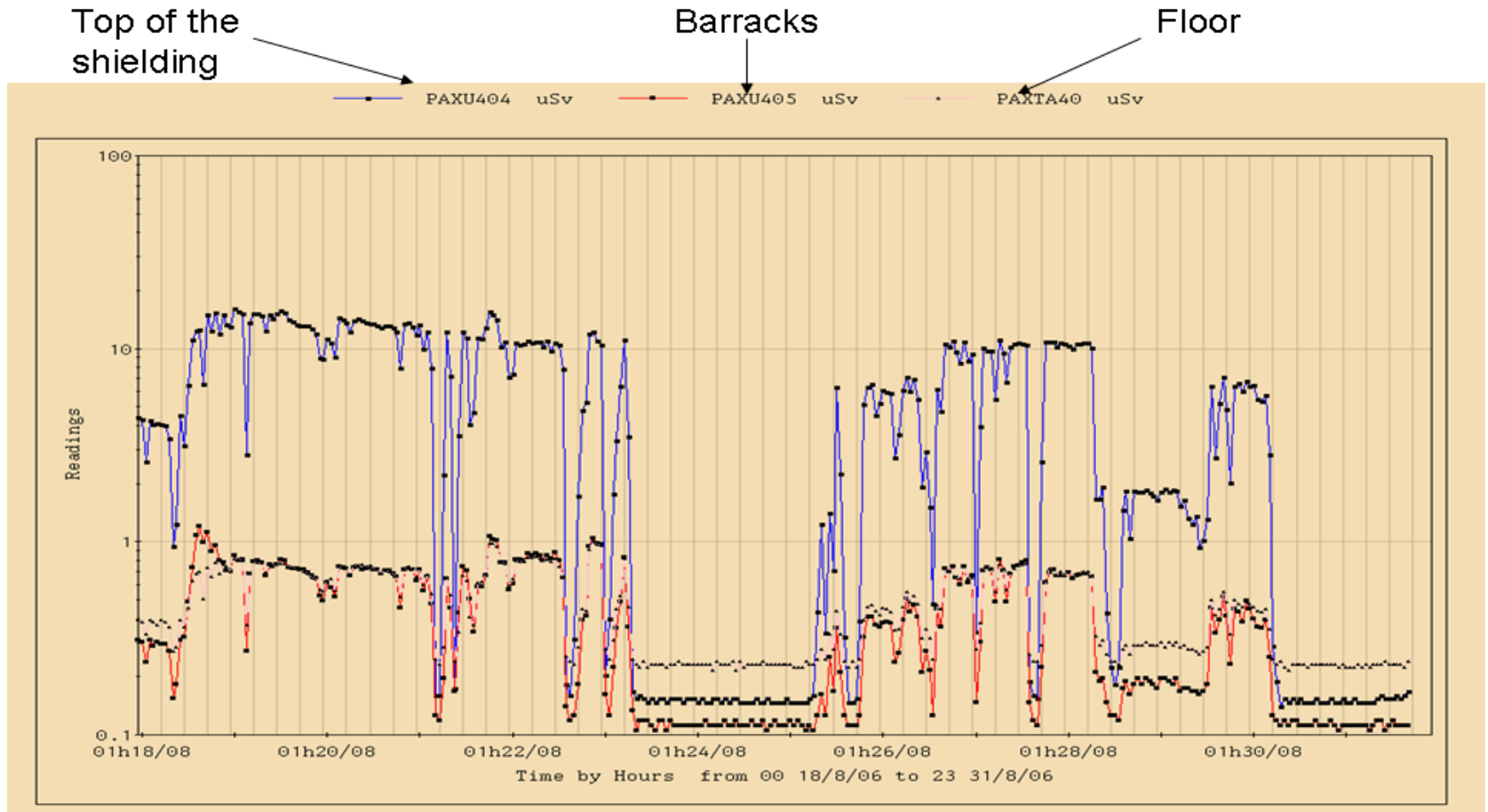
The monitors show maximum radiation values in the range of 1 uSv/h

Corresponds to 0.043% of lost particles.

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Extraction related Machine Protection (1)

- Nominal intensity for CNGS extraction **~ factor 10 above damage limit** of equipment.

- Machine protection system in place to protect extraction and transfer line equipment.

- In this talk only extraction machine protection covered.

- Passive protection + active protection

  – Passive: TPSG – absorber in front of septum magnets.

  – Active: interlocking system (monitoring of critical parameters).

    • If threshold is exceeded, extraction is not permitted.

Extraction related Machine Protection (2)

## Extraction equipment interlocking

- Girder position interlock (+/- 2mm)
  - Protection of MSE with TPSG
  - 110 mm nominal position

- MKE voltage interlock (+/-2kV)
  - 1 kV change corresponds to ~ 1 mm change at TPSG

- Bumped beam position (BPCE) interlock
  - +/- 1 mm

- Beam loss monitors in LSS4 threshold interlock:
  - Thresholds on BLM1-BLM8 to respect loss limit 0.1% of nominal
  - 38, 18, 18, 18, 18, 18, 18, 18 mGy

- Fast Magnet Current Change Monitor (FMCM) for the MSE:
  - Threshold on current change of < 0.2 %

Girder Scan - circulating beam

correlation beam loss - mGy on TPSG: circulating beam
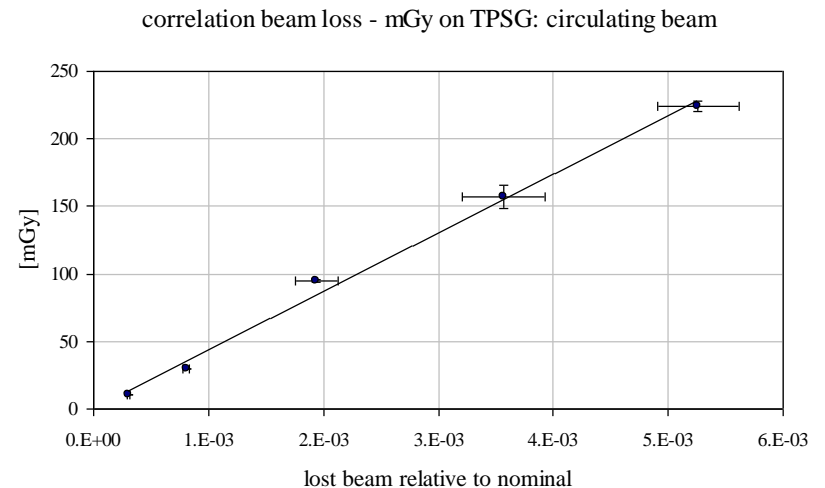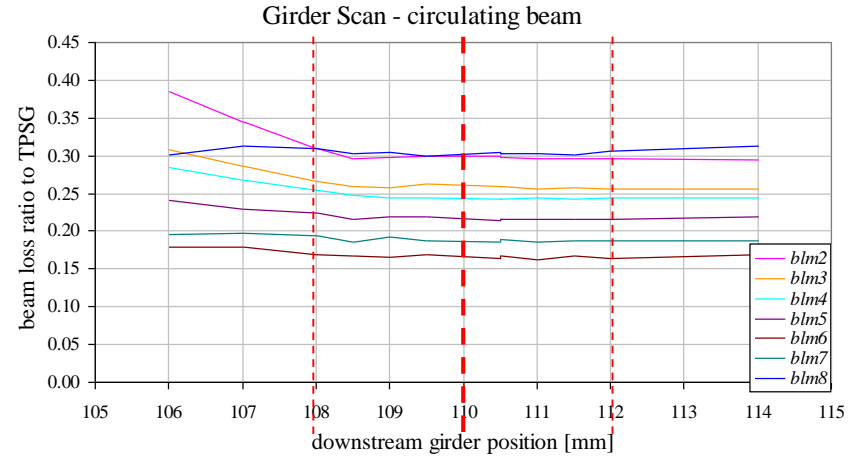
Likely Failure Scenarios: Extraction Kicker Failures

- **Failure scenarios**
  - MKE erratic (main switch)
  - MKE missing
  - **MKE erratic (clipper switches)**
  - Sweep (timing error)

- **Experiment: MKE 80 % kick, low intensity**
  - corresponds to one kicker out of 5 missing

- **Outcome:**
  - big oscillations down the line (peak > 10 mm); target out of tolerance
  - no beam loss in TT41during test
    - might be due to gain of monitors with low intensity
    - $\rightarrow$ for nominal intensity, losses in TT41 are <30 mGy.
  - TPSG/MSE high losses, but MSE protected

Difference Trajectory 40 kV (measured 39.6 kV)

Beam Loss for nominal intensity
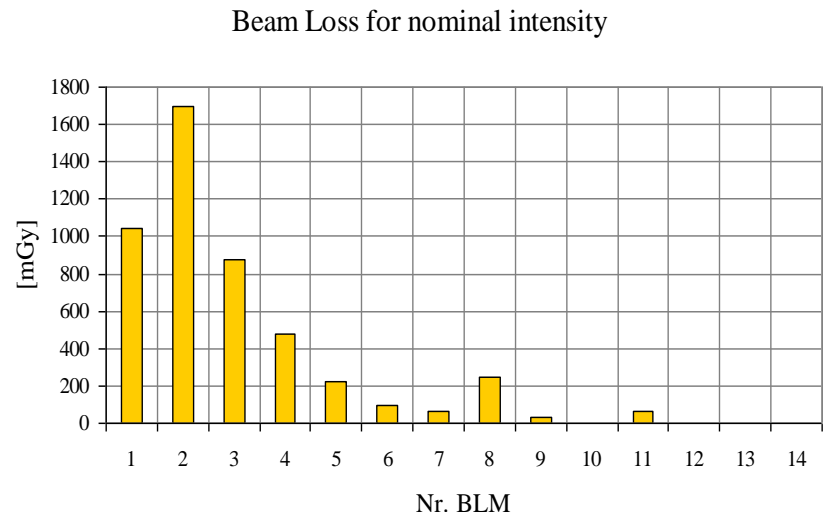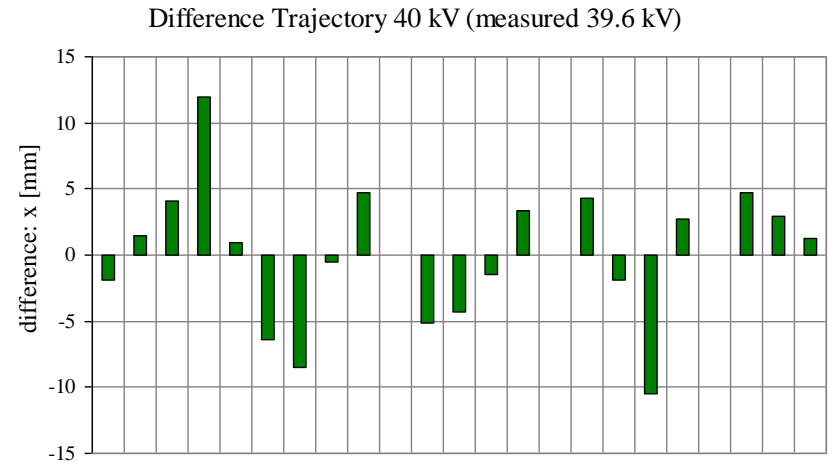
Summary

- The extraction is set up "cleanly" in the transverse plane

- "All" losses stem from beam in gap
  – Losses are acceptable concerning radiation in ECA4.

- Machine protection systems are in place to protect extraction equipment and line.
  – What about the target during kicker failures (2 mm excursions)?

- Outstanding issues:
  – Confirm "gap-losses" hypothesis (extract only second batch?)
  – Monitoring of gap population
  – Kicker gap cleaning to remove losses during extraction: with transverse damper?
  – …

MKE kicker system in LSS4

Status July 20, 2006

- End of June: main switches M2, M5 erratic problems;

  - Situation improved with grounding and conditioning.

- Up to July 15th: clipper switches erratic problems + contact erosion + divider resistors;

  - Aluminum contact changed – all installed switches;

  - Divider resistor (top) changed – all clipper switches;

  - Divider resistor (bottom) changed – C1 and C2.

- On July 15th: 1 spark in magnet #2.

- Statistic since July 15th

  - 36 hours (WE) + 12 hours (night);

  - No clipper erratic;

  - 2x M2 interlock (problem with setting tables).