LHC Injectors Upgrade

Beam Gas Ionization monitors for SPS and PS

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BI_LIU review, October 3rd, 2013

CERN

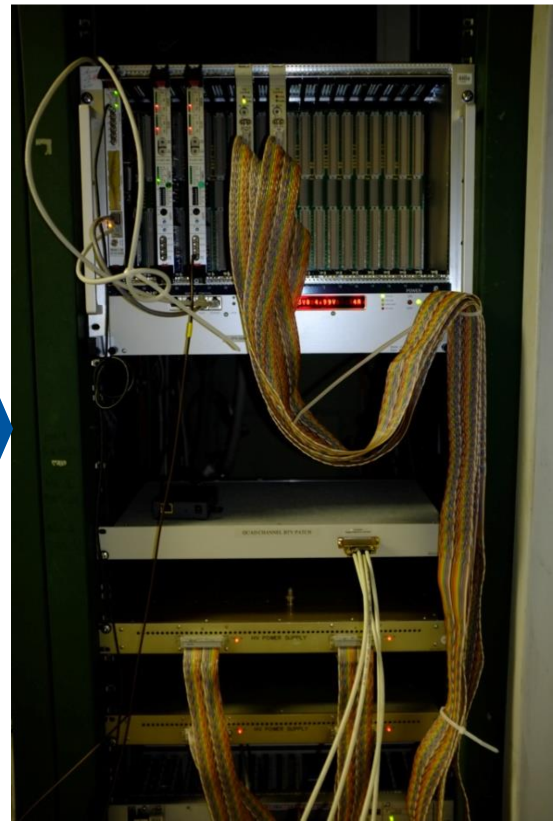
Outlook

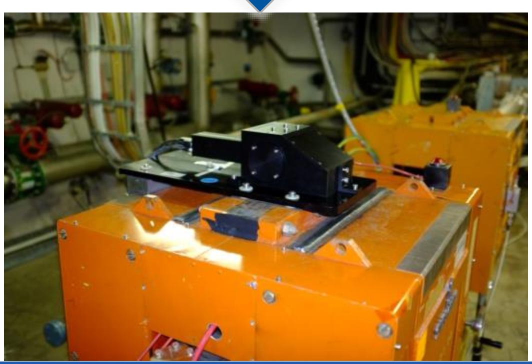
- SPS BGI Renovation
- Specification for after LS1
- Additional works on SPS BGI
- PS BGI requirements and first specification
- Technology choice
- Location
- Preliminary plan for PS device

SPS BGI renovation

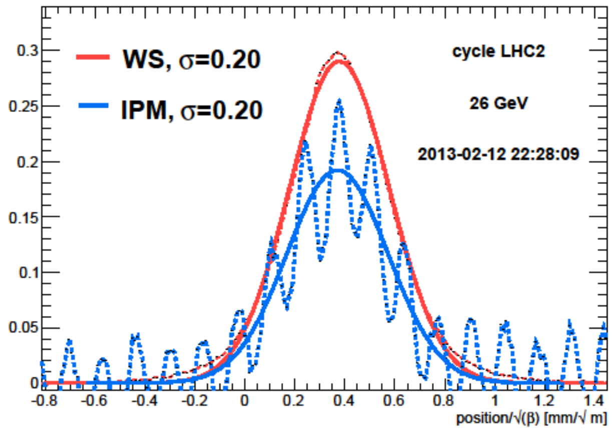
- During winter TS 2011/2012 SPS BGI was renovated:
  - MCP exchanged
  - Electronics (surface and tunnel) exchanged to the same as in LHC.
  - Optical systems and cameras exchanged to the same as in LHC.
- System ready: June 2012.
- Struggling with noise on analog video signal.
- Finally remedy found by cable shielding and different signal amplifier.

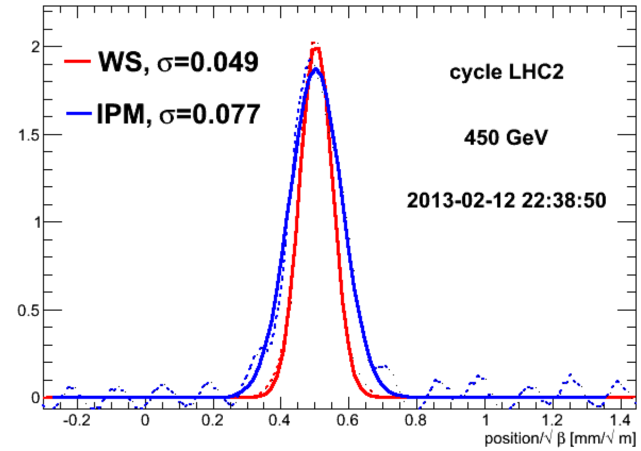
Renovation – surface electronics and cameras



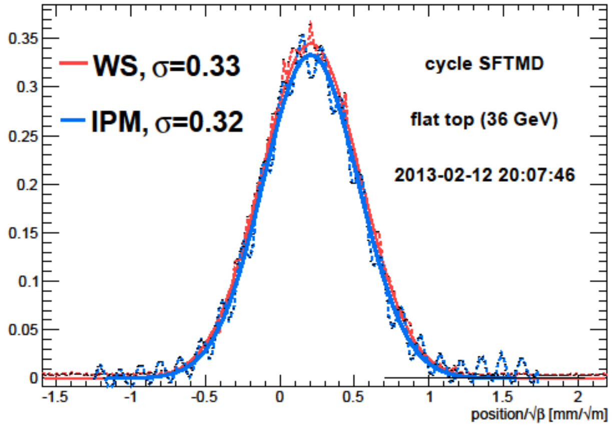


February 2013 measurements





ε=1.1 µm



<u>Profile broadening due to space charge (as LHC)?</u>

- Can we live with that?
  (repeatability, relative measurement)
- Stronger magnets?
- Correction procedure – ongoing study.

Requirements for after LS1

Discussion at MSWG 2013.07.02 (Karel):

- Measure 10 fps during the ramp (currently 1 fps).
- Important is measurement for LHC beams – space charge

Checking potential for 10 fps acquisition:

- Ana: image acquisition is 60-70 ms. Limit ~15 Hz per camera.
- Does not scale linearly with number of cameras.
- Bogna: works on achieving 10 fps, as for now it seems possible for a single

camera in a crate. Ongoing, to be checked with 2 cameras.

Other LS1 works

- Renovation of detector cages: the same electrodes as in LHC (now aluminium electrodes).
- Making cameras more rad-hard (chip shielding).
- Improve camera control.
- Add vacuum and temperature measurement.
- Standard logging.
- Magnet removal and recabling (MP issue, G. Le Godec).
- Adding synchronization with machine in order to work on bunch-by-bunch measurements.

Budget LIU SPS

- 2013: 50 kCHF
- 2014: 50 kCHF
- New magnets (5) would cost ~300 kCHF (P. Thonet).
- The same magnets as in LHC.
- Power converters:~ 100-200 kCHF. (tbc)
- Time of development: 2 years.

PS BGI

- Continuous measurement during the cycle.
- bunch-by-bunch and turn-by-turn measurements in some moments during the cycle.
- Wire scanners will be breaking with HL-LHC beams.

PS beams – examples

beam	SPS ftarget	TOF	EASTA	LHC 25 ns 72 bunches
Injection				
Ek [GeV]	2.0	2.0	2.0	2.0/1.4
Bunch nrb	8	1	1	6
Charges/b	3.1E12	8E12	4E11	1.5E12
Bunch len [ns]	150	190	170	180
εH/V [μm rad]	7.6/5.4	9.2/7.8	1.5/1.5	1.5
Extraction				
Ek [GeV]	14	20	24	26
Bunch nbr	420 (deb)	1	1	72
Charges/b	~5E10	8E12	3.8E11	1.25E11
Bunch len [ns]	5	50	debunched	4
εH/V [μm rad]	11/8	12/10	-	1.5

EDMS 1157752, document in work

Beam specs to be updated after October review of RLIUP.

Preliminary OP specification:

- Maximum number of bunches: 72
- bunch-by-bunch and turn-by-turn at injection, extraction (maybe transition) for 5-10 ms (5000 turns) – burst mode.
- A sliding window of burst mode.
- No multiplexing (H and V at the same time).
- Beam size: 0.5-60 mm (that is difficult).
- No need during RF bunch splitting/merging – results difficult to interpret in H plane due to large dispersion.
- Normal mode: 100-1000 acquisitions/s (bbb)
- Used mainly for qualification of LHC beams during filling – must work in pulse-to-pulse mode (PPM).

Choice of principle

- Electron or ions?
  - Fast measurement = electrons.
  - Magnets needed (~0.2 T).
- Optical or electrical readout system?
  - Electrical readout easier fulfills spec.
  - Electrical readout allows to save space (needed by optical mirror) and construct magnets with smaller aperture (impact on cost).
  - Beams are large, no need for optical readout.

Technology

- Electron-reading BGIs with multi-strip readout used in Fermilab, BNL and GSI
  - Design can be based on one of these design (investigation ongoing) – might shorten the design/development time
- Two readout chips considered: Timepix3 and QIE10 – both considerably resistant to radiation.
  - Acquisition: technical student (Oliver Keller) full time on this project since October 1st.

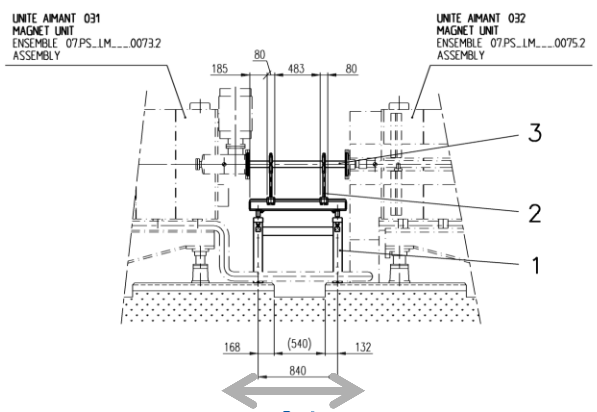
Magnets

by Dominique Bodart

- Requirement: good field region of 50mm, field 0.2 T
- Iron yoke type corrector magnet
- Number of corrector magnets to close the bump: 1
- 2 types of magnets shall be used because of vacuum chamber shape
- Particular attention on vertical corrector because the aperture needed is 180 mm
- Preliminary study ongoing, 2D simulation show acceptable field homogenity
- Cost 100-200kCHF (for 6 magnets including spares)

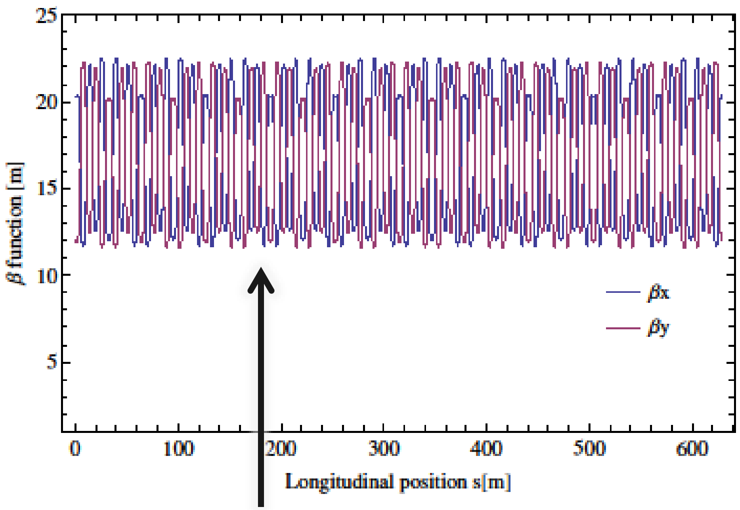
Location

- Horizontal device: SS32
- Vertical device: SS33



~84 cm

SS should be ok for radiation levels once the CT extraction replaced definitely by MTE



SS32

Time line and budget

- October 2013: start working on electrical/Silicon readout magnet simulations, design (or integration of other design)
- Spring 2014: technical proposal
- Summer 2014-end of 2015: construction
- Winter 2015/2016 installation
- Budget 2014: 60 kCHF feasibility study – spec challenging
- Whole project (material): ~400 kCHF
  - Vacuum tanks: 100 kCHF
  - Electronics, cables, installation: 100 kCHF

Conclusions

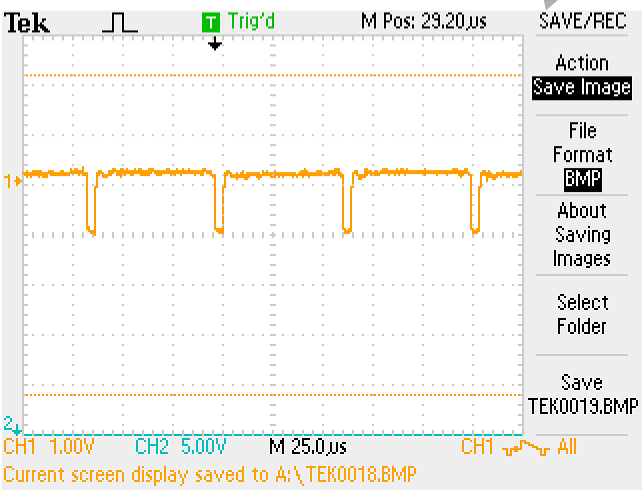
- SPS BGI should work with a few Hz acquisition.
- Space-charge distortion of profile for low emittance beams probably already visible.
- PS BGI study started.
- Objective: bunch-by-bunch and turn-by-turn measurements at injection and extraction.
- Installation winter 2015/16.

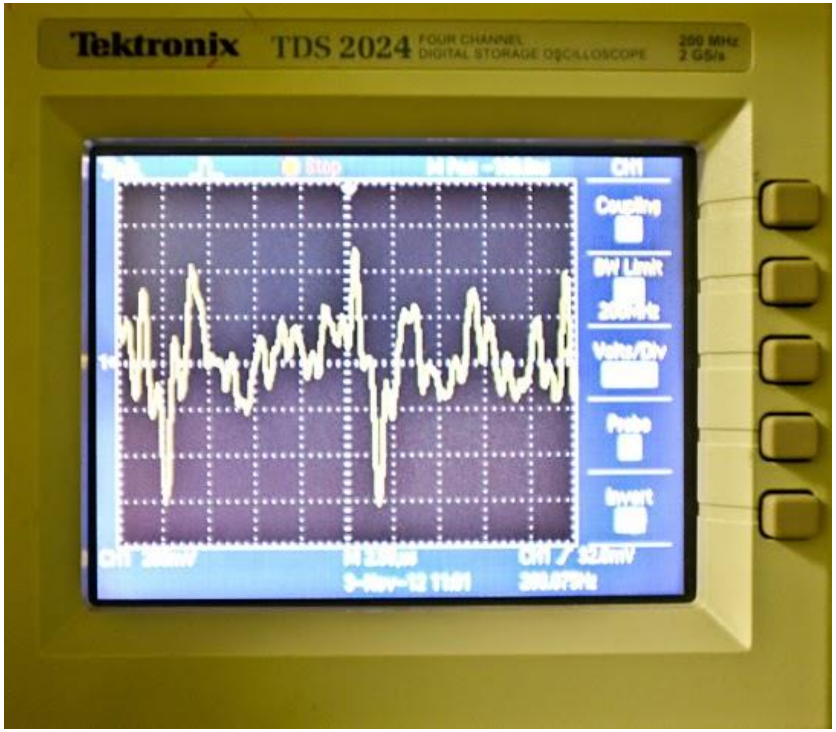
THANK YOU FOR YOUR ATTENTION

Backup slides

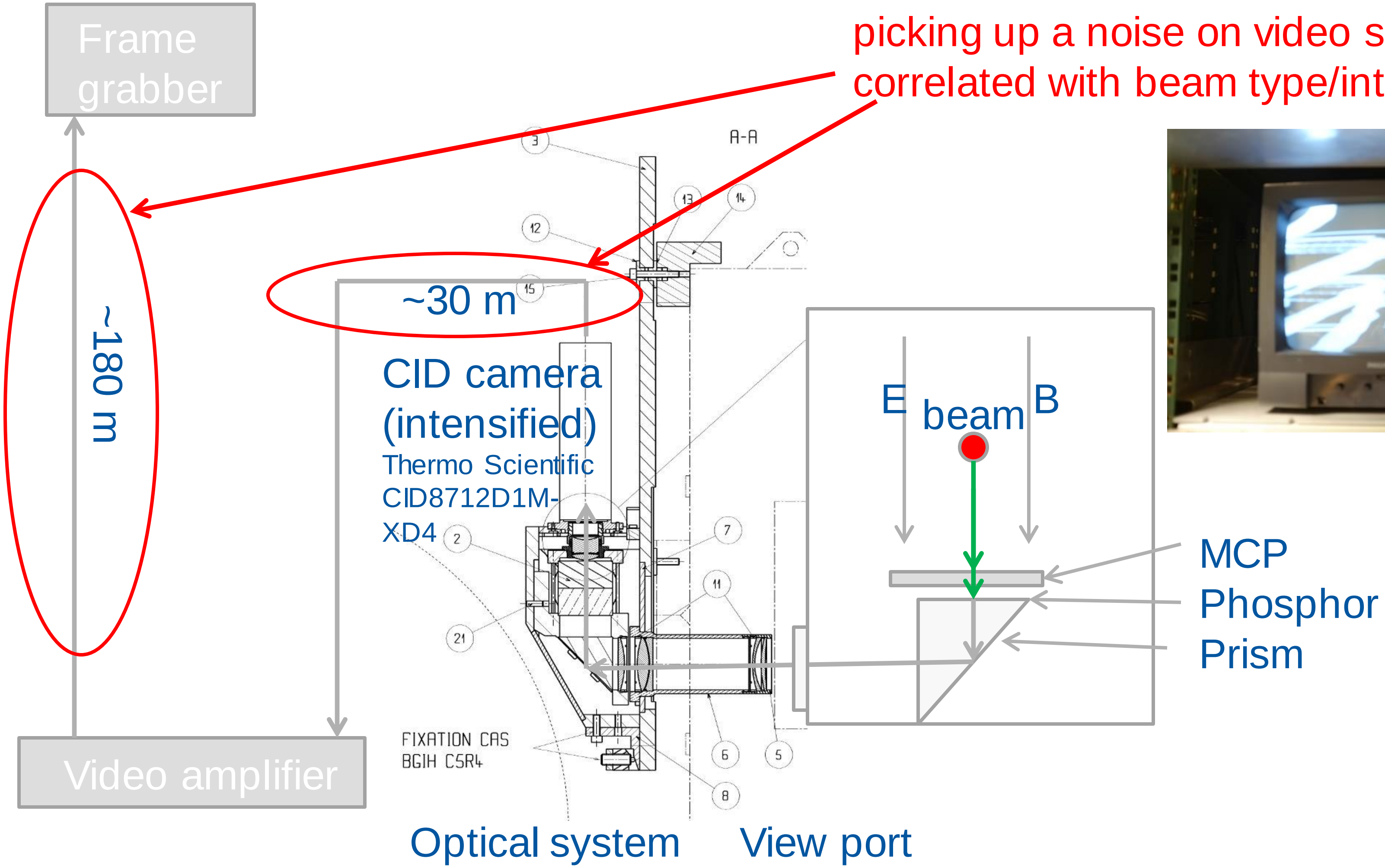
Video signal noise problem

- Signal with beam
- Signal in the lab





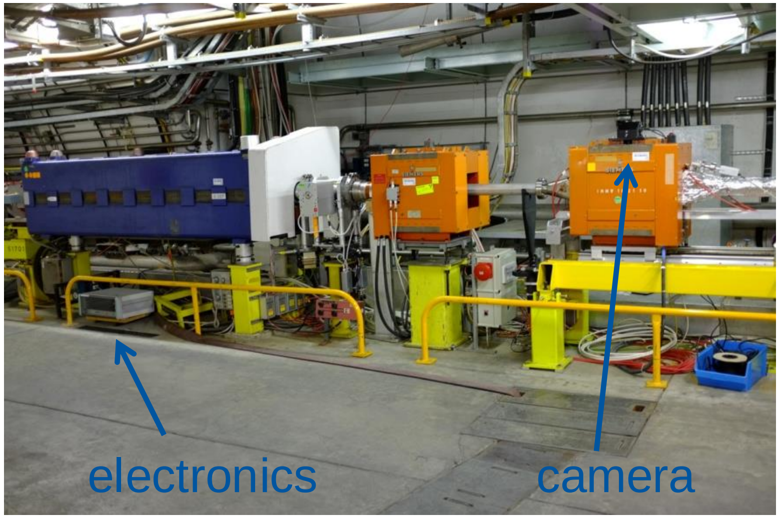
Video signal noise problem



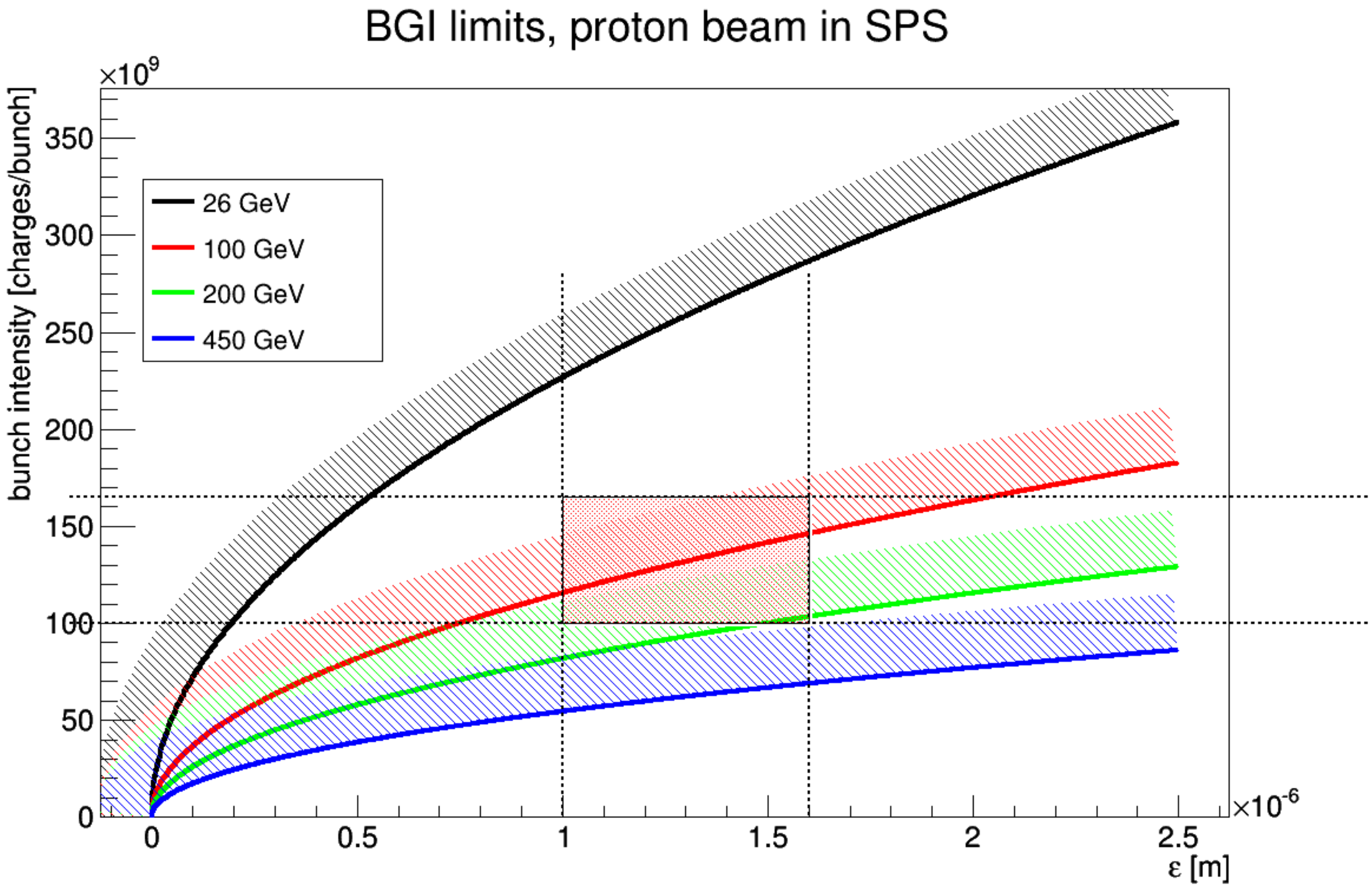
2012.10.02

Video signal noise - remedy

- Cable shielding, moving electronics away from the beam and exchange of video signal amplifier



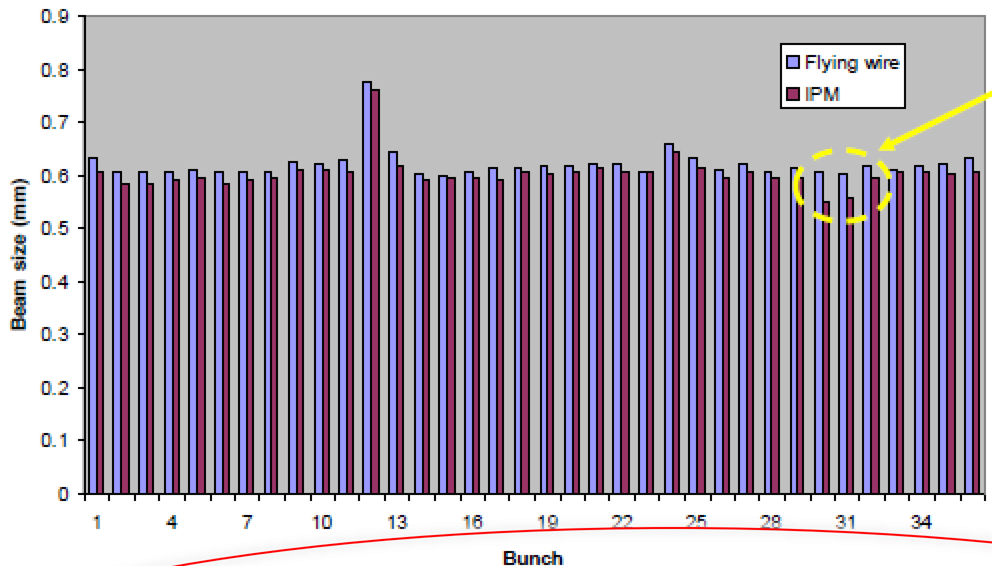
Space-charge limit: dv/v<0.1



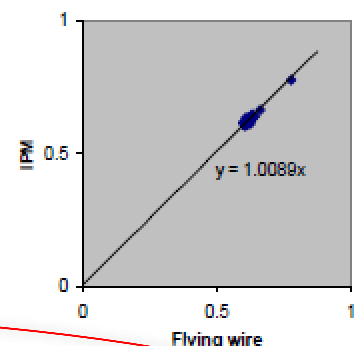
M. Patecki

Space-charge in other machines

Flying wire comparison



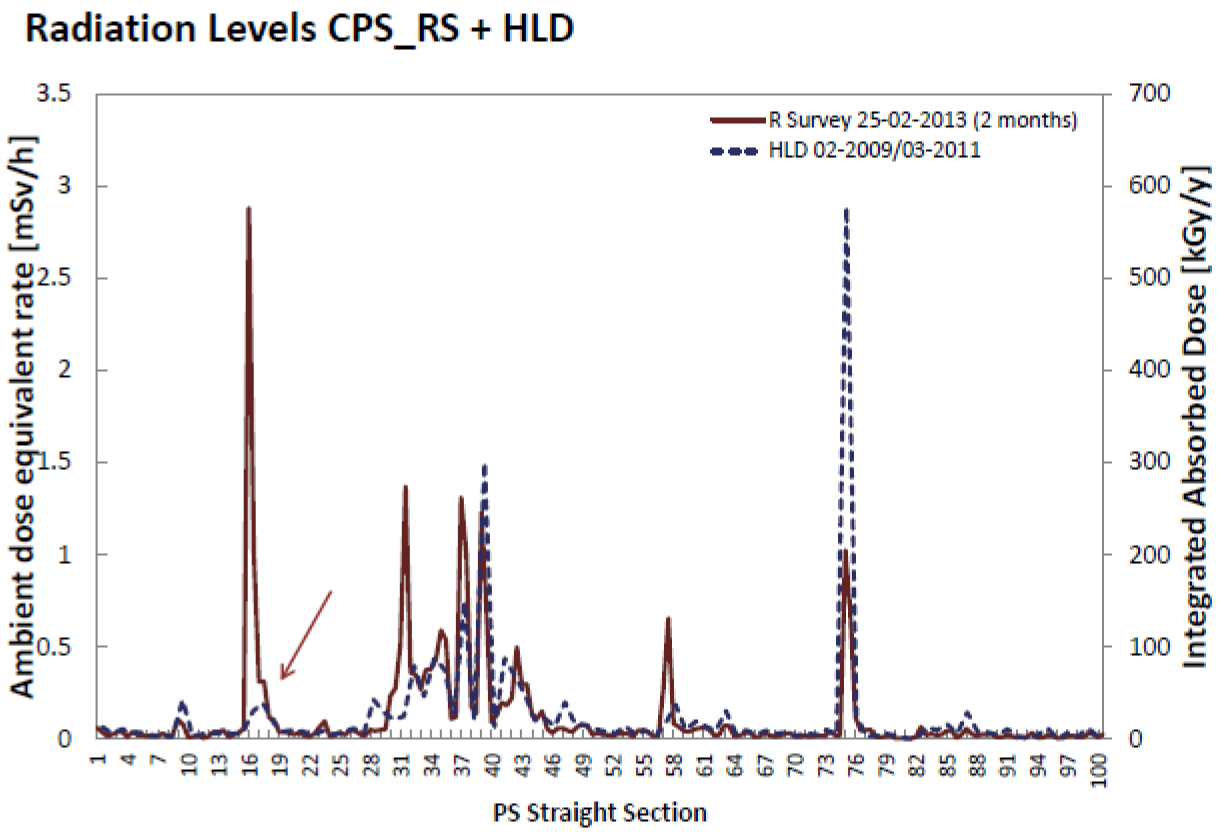
Known electronics problem (cross talk from revolution marker pulse)



Comparison of vertical beam size from IPM and nearby Flying Wire.
Tuning of abort gap cleaner timing had caused blow-up of certain bunches.
From MAD lattice file, expect a 13% wider beam at Flying Wire. See ~1%.

15/4/2013 Tevatron IPMs

Radiation in SS31 and SS32



PS BGI A.D. 1968

PAC 1969

THE CPS GAS-IONIZATION BEAM SCANNER

C.D. Johnson and L. Thorndahl
CERN, Geneva, Switzerland

Summary

A non-destructive beam scanner was instal-led in the CPS ring early in 1968. Deriving a signal from the electrons liberated by the pro-ton beam from the residual gas in the vacuum chamber and using a crossed el… tric and magnet-ic fields system of electro… ction, the scanner gives the projec… density dis-tributions in the hori… tical planes. Spatial re… er than 1 mm.

An importan… use of a single collector wh… ctrons from a slice of the bea… ero equipotential sur-face. … potential surfaces are arra… the beam and scanning is … placing these equipotentials … region of the beam. In parti-… zero equipotential, which always … rough the detector, is scanned right … the beam.

References

1. HORNSTRA, F. and DELUCA, W.H., Non-destruc-tive beam profile detection systems for the ZGS, ANL internal report, 1967

Argonne, 1967

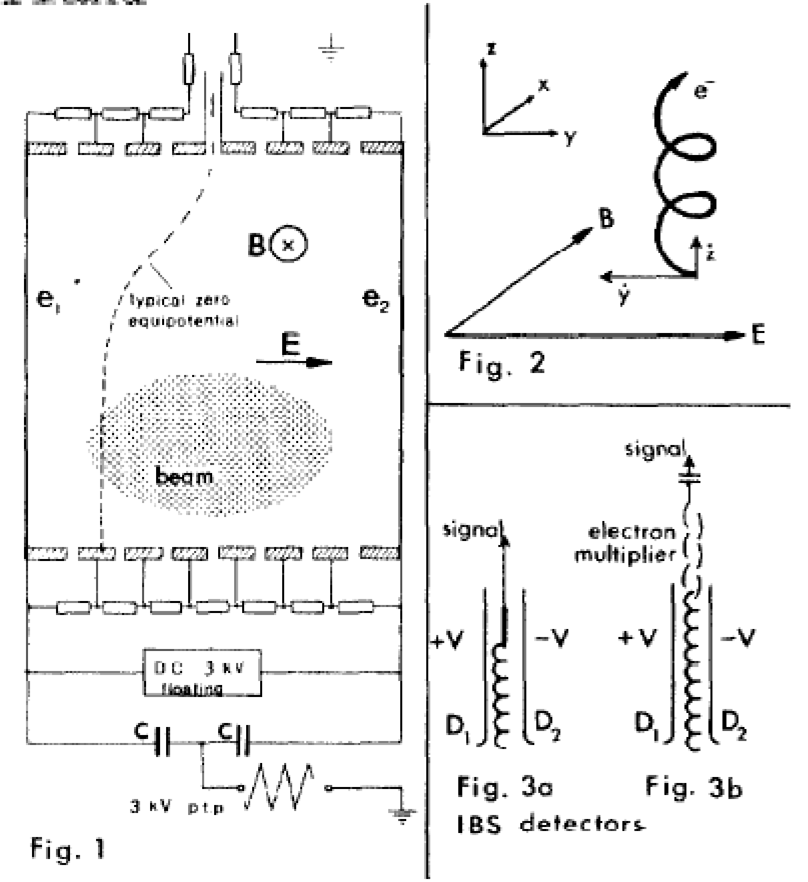
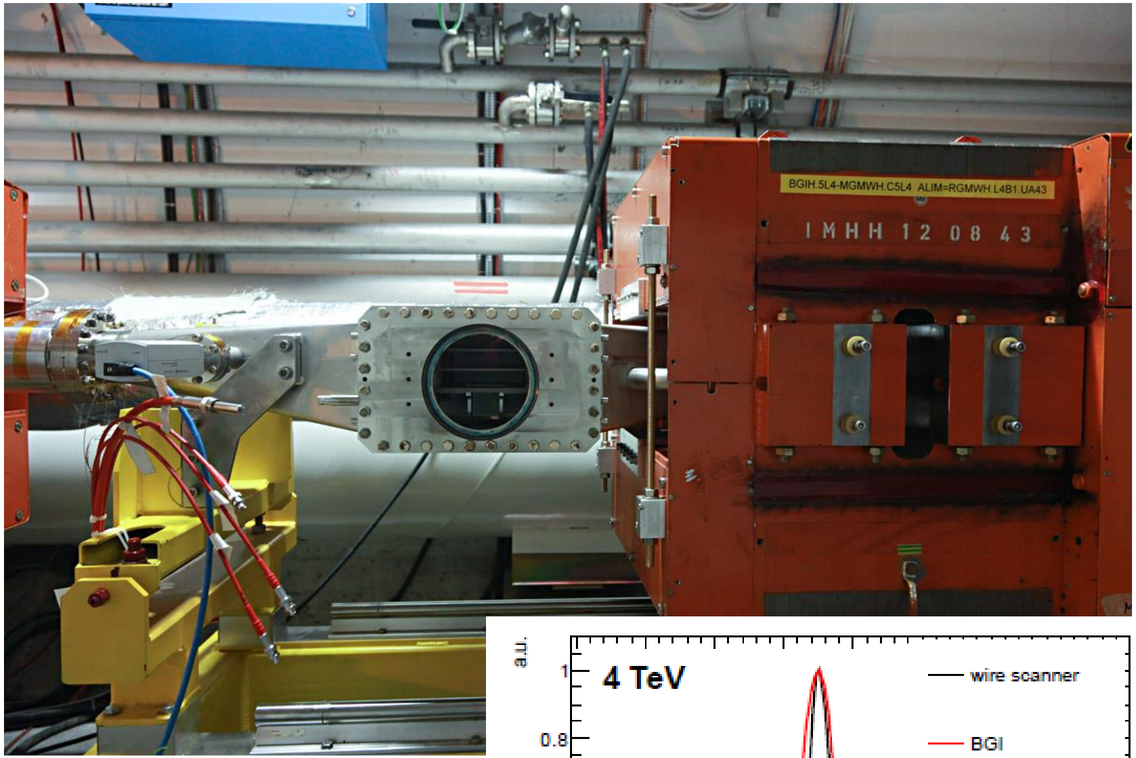


Fig. 1

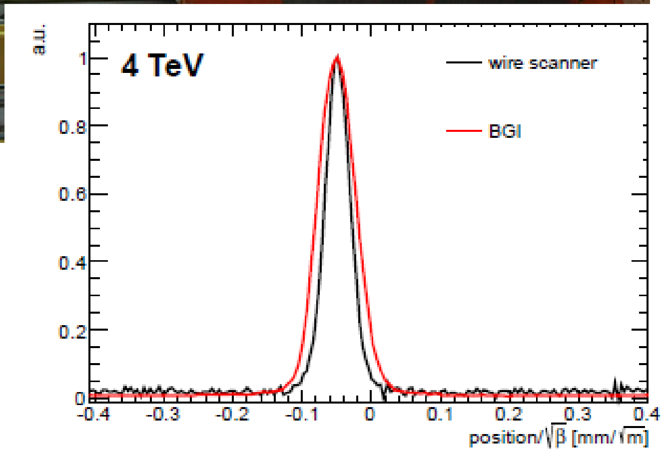
Fig. 2

Fig. 3a Fig. 3b
IBS detectors

Emittance – ionization profile monitor



In LHC most beams turned out to be too small and electrons were kicked out of their initial locations leading to profile distortion.



Profile broadening due to electron interaction with bunch charge