Beam Gas Ionization monitor for PS

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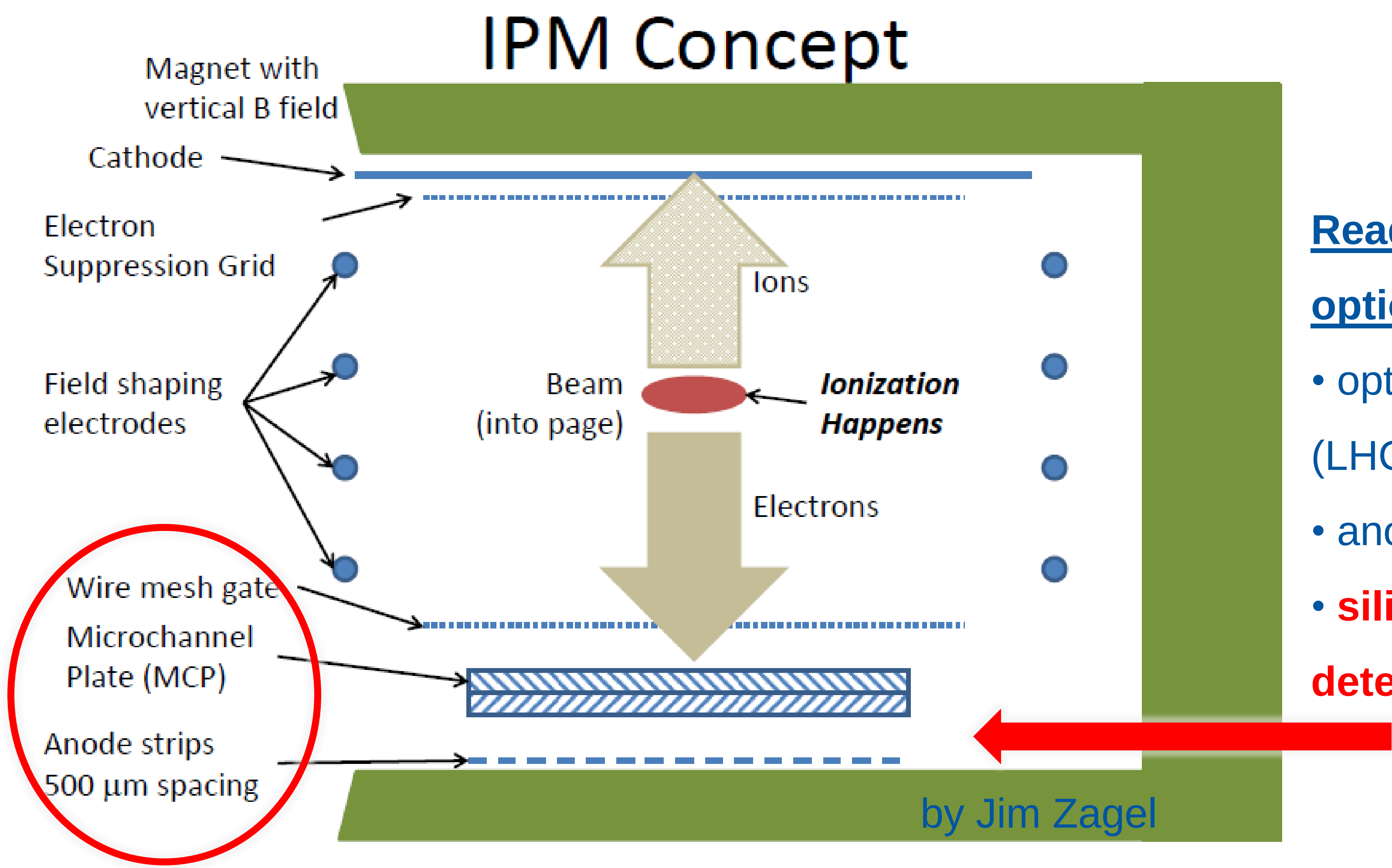
LHC Injectors Upgrade

CERN

Introduction

- Beam Gas Ionization monitors (BGI) is a device to measure transverse beam size (and therefore beam emittance) due to ionization of rest gas in the vacuum pipe.
- BGIs operate on many machines, also at CERN: LHC, SPS, LEIR
- Optimizing beam emittance is crucial for HL-LHC.
- Emittance produced in pre-accelerators cannot be improved.
- PS is a machine where a lot of gymnastics with beam is done – many processes can affect emittance.
- Therefore strong need to measure and control emittance in PS.

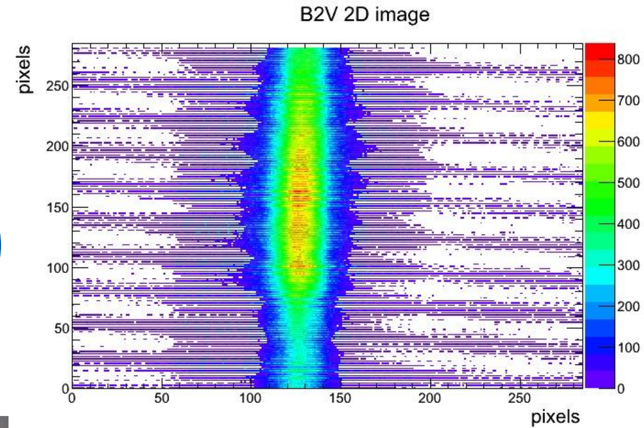
Beam gas ionization monitor

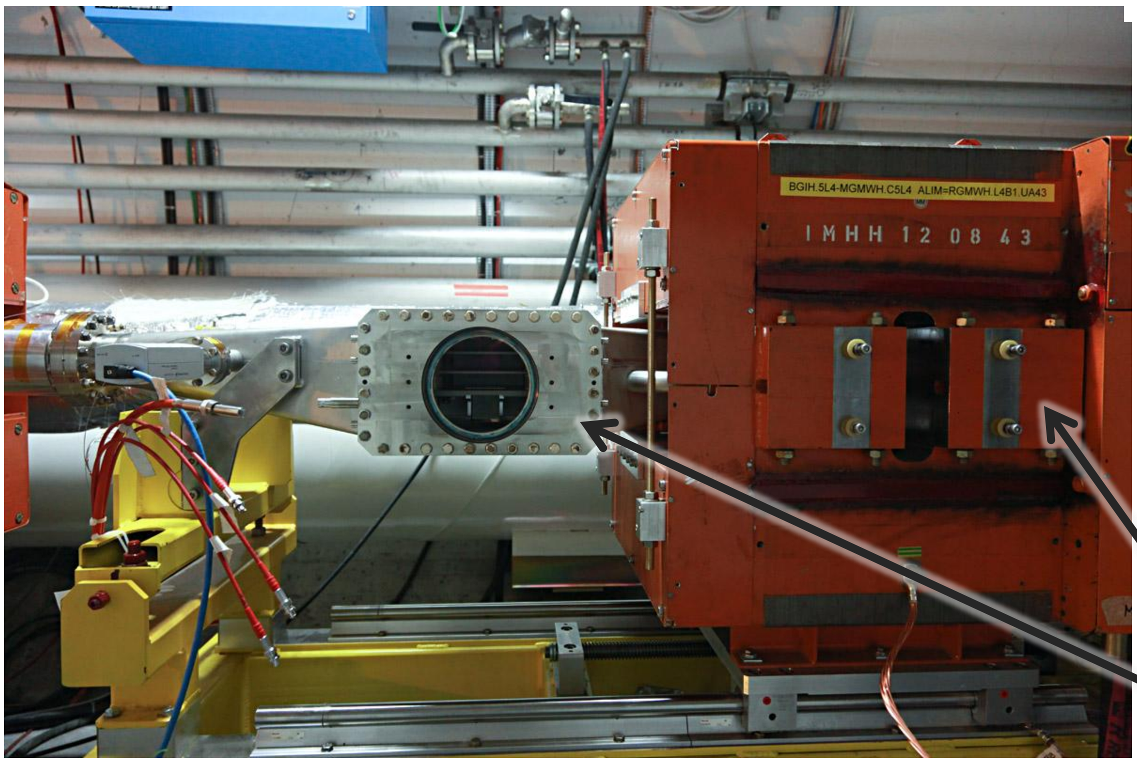


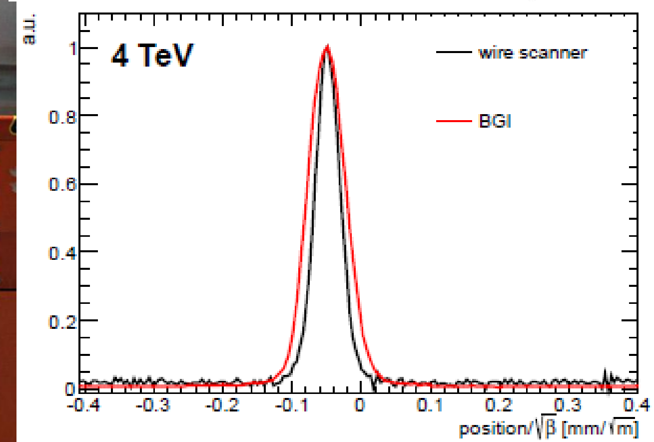
Readout options:

- optical readout (LHC and SPS)
- anode strips
- **silicon detector**

Current experience: LHC and SPS BGIs (also LEIR)







Example of ion beam measurement in LHC.

Magnet

HV cage

PS BGI basic specification

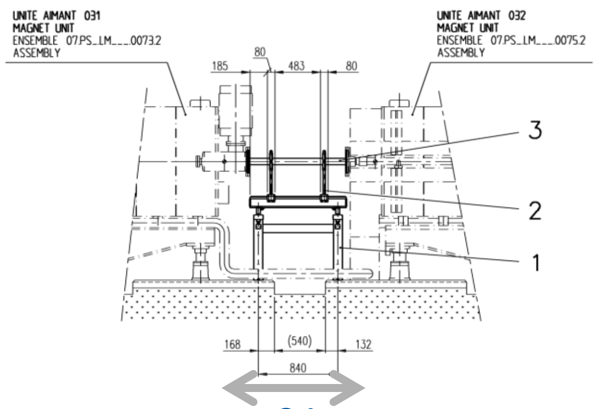
- Typical beam size: 0.5-5 mm (LHC beams), cover ~ 5 cm
- maximum 72 bunches max, 25 ns bunch spacing
- 10^{12} protons per bunch, 10^{10} Pb^{82+}ions per bunch
- bunch properties change during cycle (splitting, merging)
- Basic mode: continuous measurement during the cycle averaged over all bunches (2.1 s) – 0.1-1 kHz
- Normal mode: continuous bunch-by-bunch measurement during the cycle - 0.1-1 kHz
- Burst more: turn-by-turn measurements (1 turn = 2.1 us) at chosen moment of the cycle (for about 5000 turns)

Choice of principle

- Electron or ions?
  - Fast measurement = electrons.
  - But magnets needed (~0.2 T).
- Optical or electrical or Si pixel readout system?
  - Electrical/Si pixel 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.
  - Probably Si pixels and Timepix chip will allow to get rid of MCP

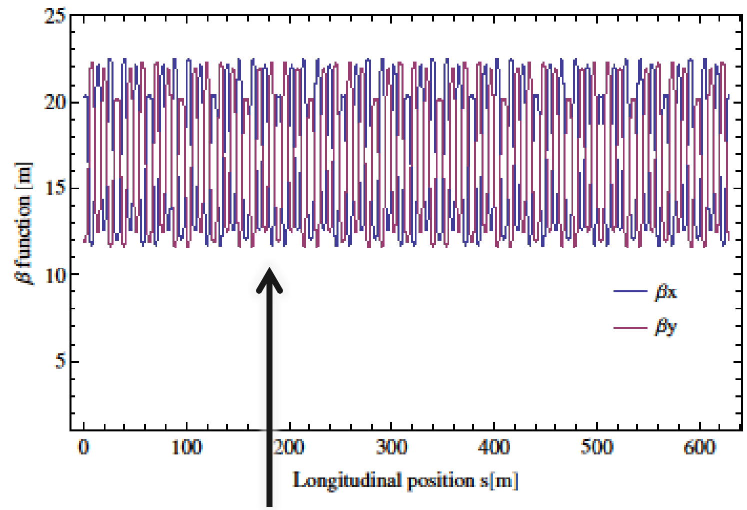
Location

- Horizontal device: SS32
- Vertical device: SS33



~84 cm

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



SS32

PS BGI and Timepix3

- between 300 and 50000 electrons/bunch (25 ns) generated due to ionization – large dynamic range.
- Electron energy 2-20 keV (adjustable, regulate pixel occupancy).
- Electric “shutter” (wire mesh) to gate on electrons from a chosen bunch only – this will be tricky because of bunch splitting procedure.
- At first look Timepix3 should withstand the radiation in PS.
- Its main advantage over electrical readout (anode strips) is lack of MCP, which suffers from non-uniform gain and ageing.

Time line and budget

- October 2013: start working on electrical/Silicon readout magnet simulations, design (or integration of other design)
- Spring 2014: technical proposal and decision
- Summer 2014-end of 2015: construction
- Winter 2015/2016 installation of prototype
- Budget has been allocated for feasibility study.

Summary

- Need of continuous beam emittance measurement in PS.
- Study started.
- Use of Si detector with Timepix3 chip seem to fulfill main requirements and allows to get rid of MCP.
- Silicon detector in BGI has never been used before.
- Prototype installation in winter 2015/16.

THANK YOU FOR YOUR ATTENTION

Backup slides

PS BGI A.D. 1968

THE CPS GAS-IONIZATION BEAM SCANNER

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

PAC 1969

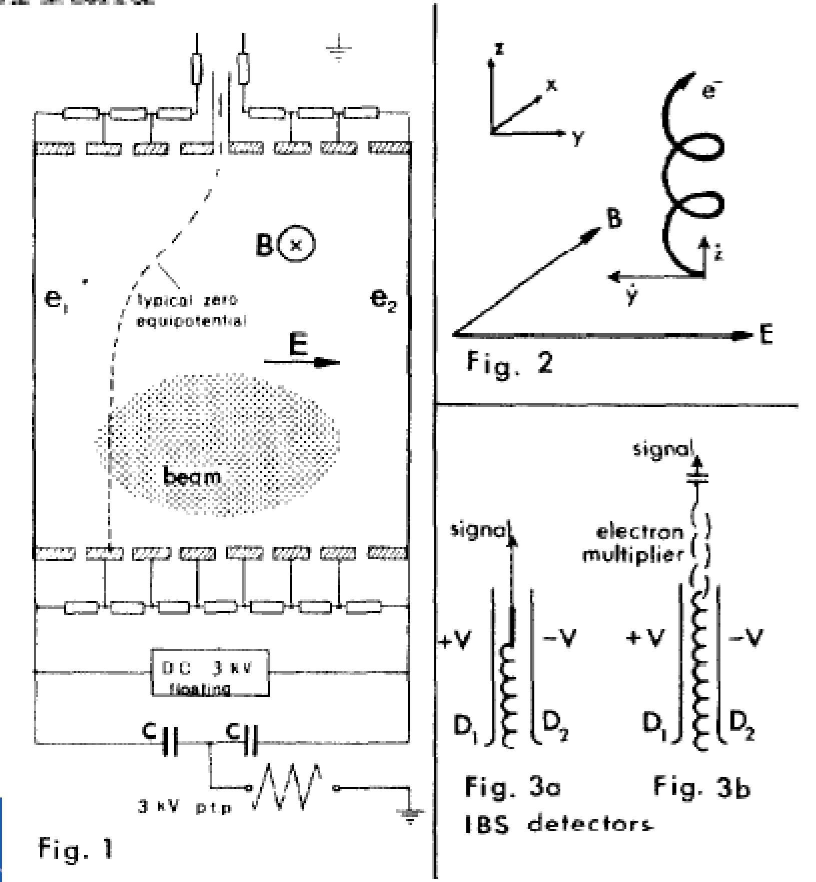
Summary

A non-destructive beam scanner was installed in the CPS ring early in 1968. Deriving a signal from the electrons liberated by the proton beam from the residual gas in the vacuum chamber and using a crossed el[...]tric and magnetic fields system of electro[...]ction, the scanner gives the projec[...] density distributions 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[...]ro equipotential surface. [...]potential surfaces are arra[...] the beam and scanning is [...]placing these equipotentials [...] region of the beam. In particular [...]ero equipotential, which always [...]ough the detector, is scanned right [...] the beam.

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

Argonne, 1967



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.

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)

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).

Radiation in SS31 and SS32