Current status of the optical based SPS and LHC BGI profile monitors

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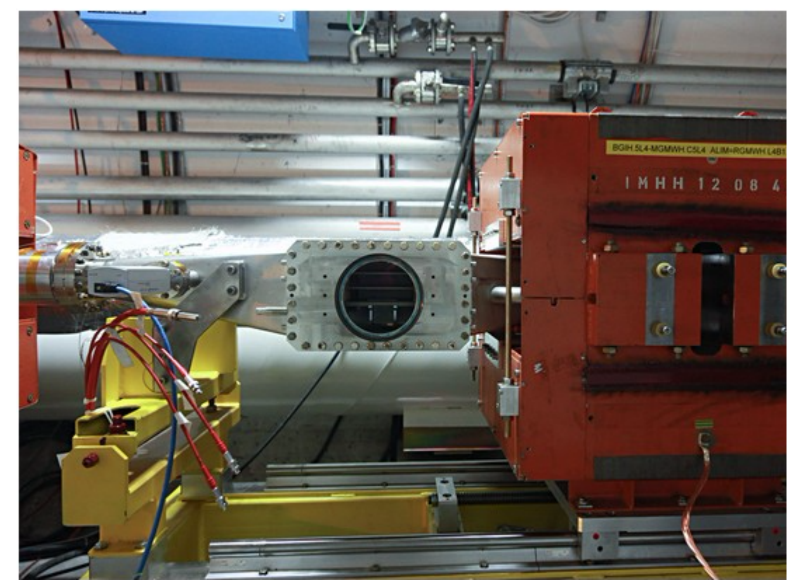
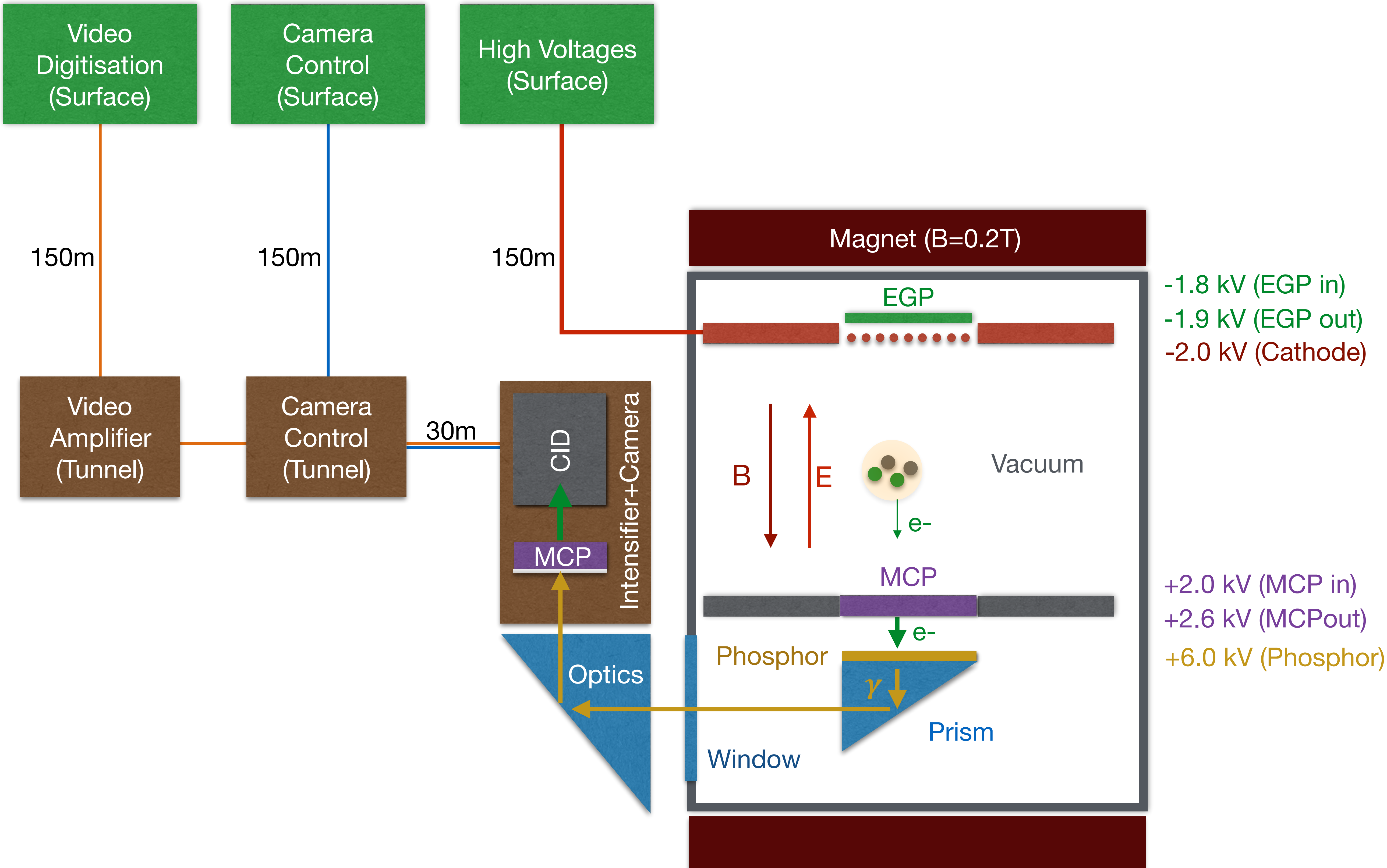
Talk outline.

1. Design overview.
2. Experience and status of the CERN optical based:
   - SPS BGI profile monitors.
   - LHC BGI profile monitors.
3. Outlook.



Beam Gas Ionisation (BGI) profile monitor = IPM

Design overview.

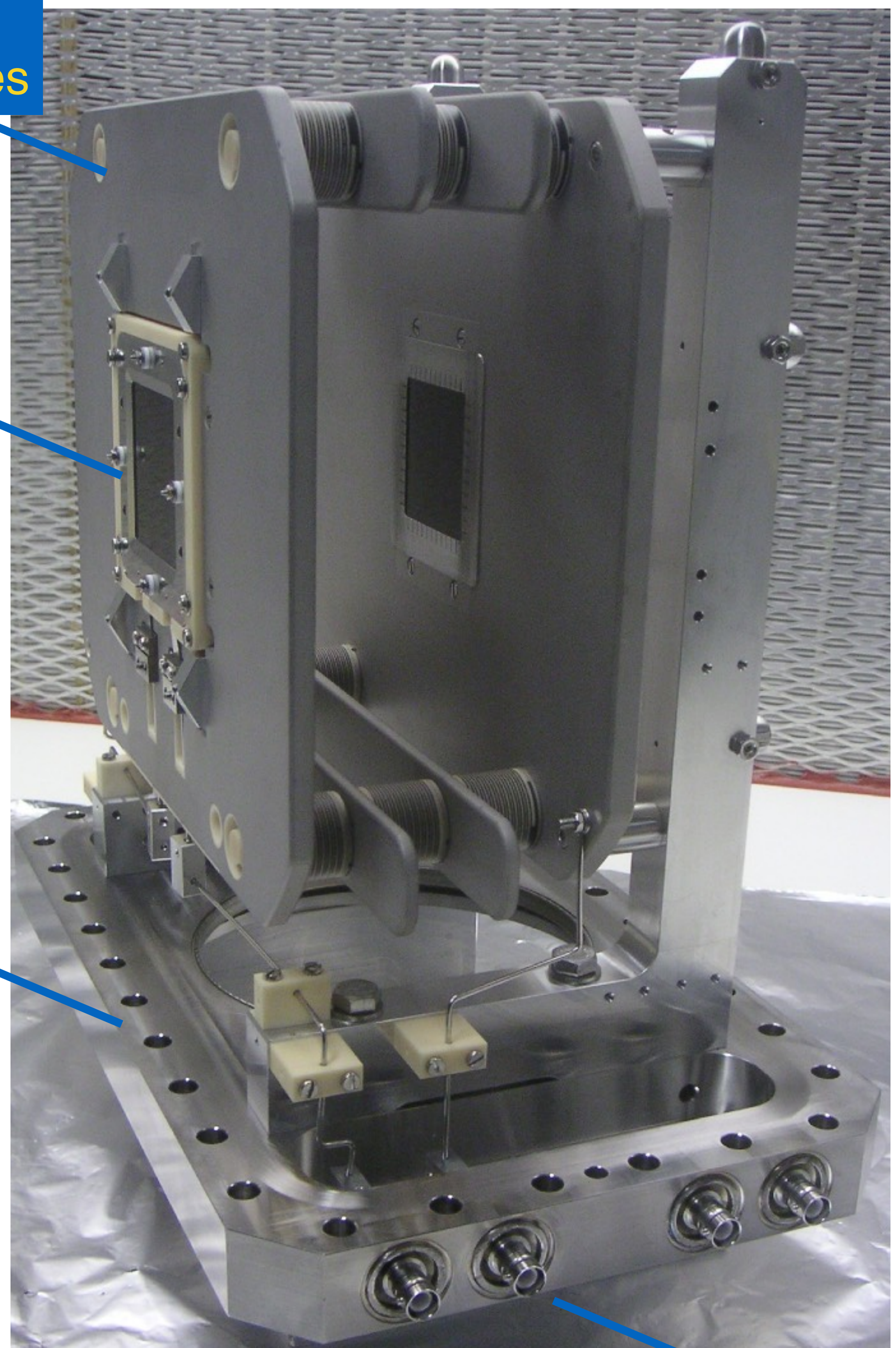


Field cage & MCP/Phosphor “Amplifier”.

NEG coated ceramic electrodes

EGP

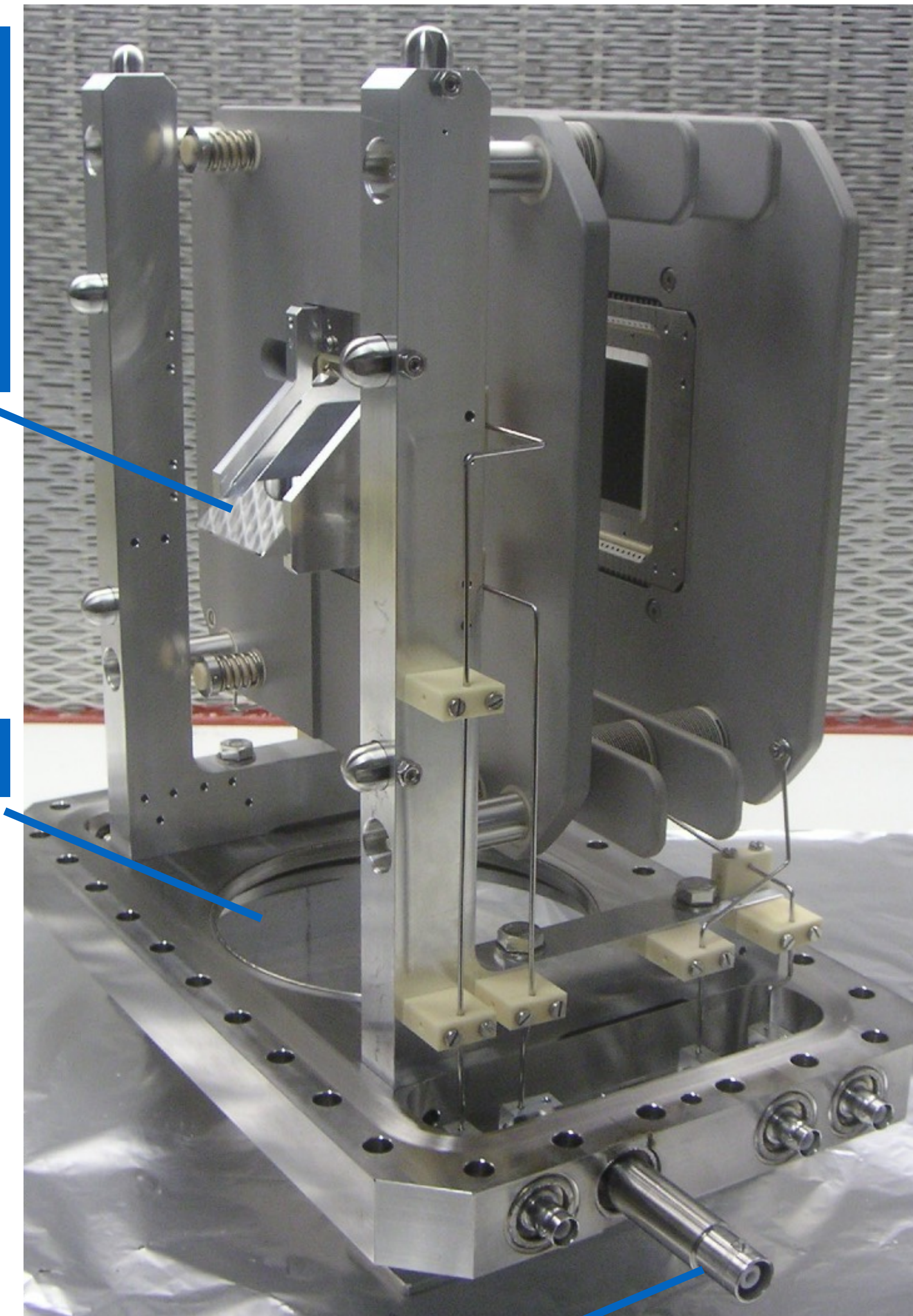
Vacuum flange with helicoflex seal



SHV feedthroughs

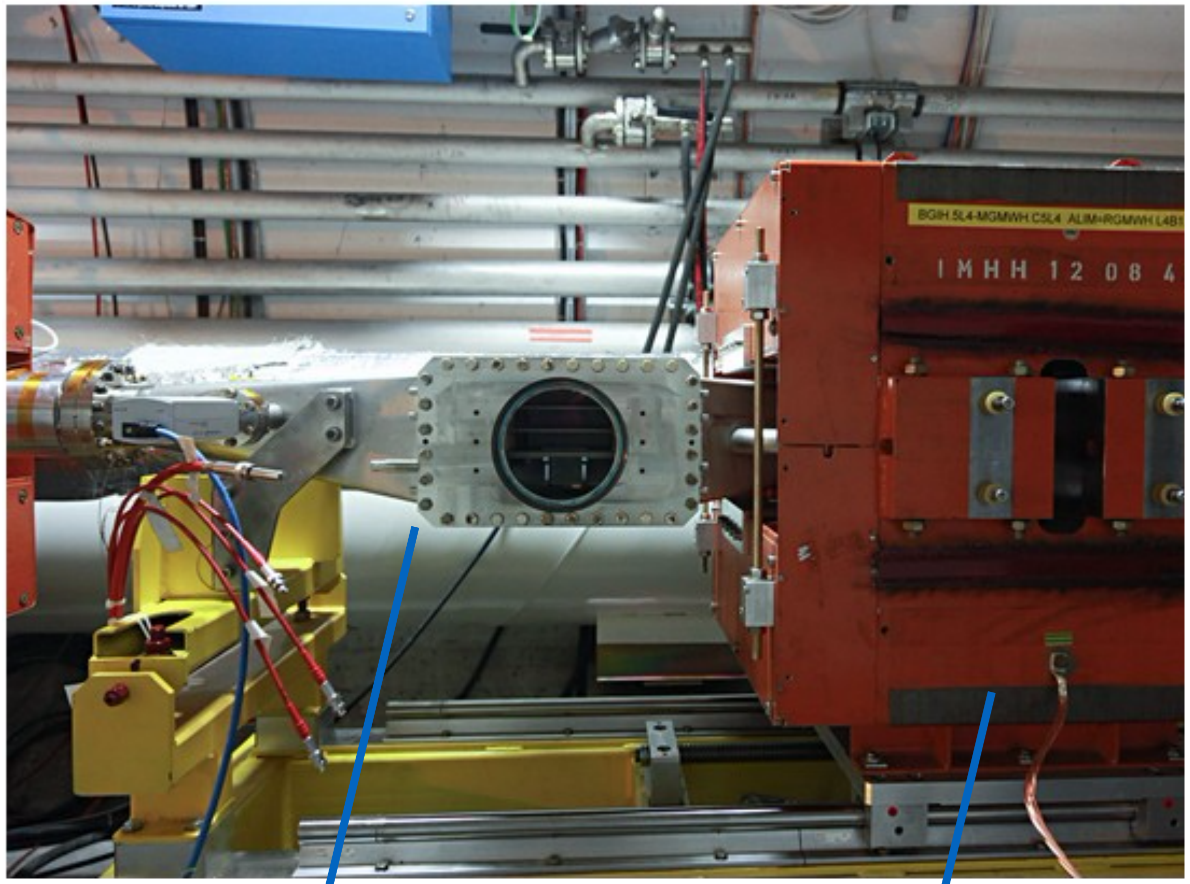
“Amplifier assembly” MCP + Prism coated with phosphor & Al mirror

UHV viewport



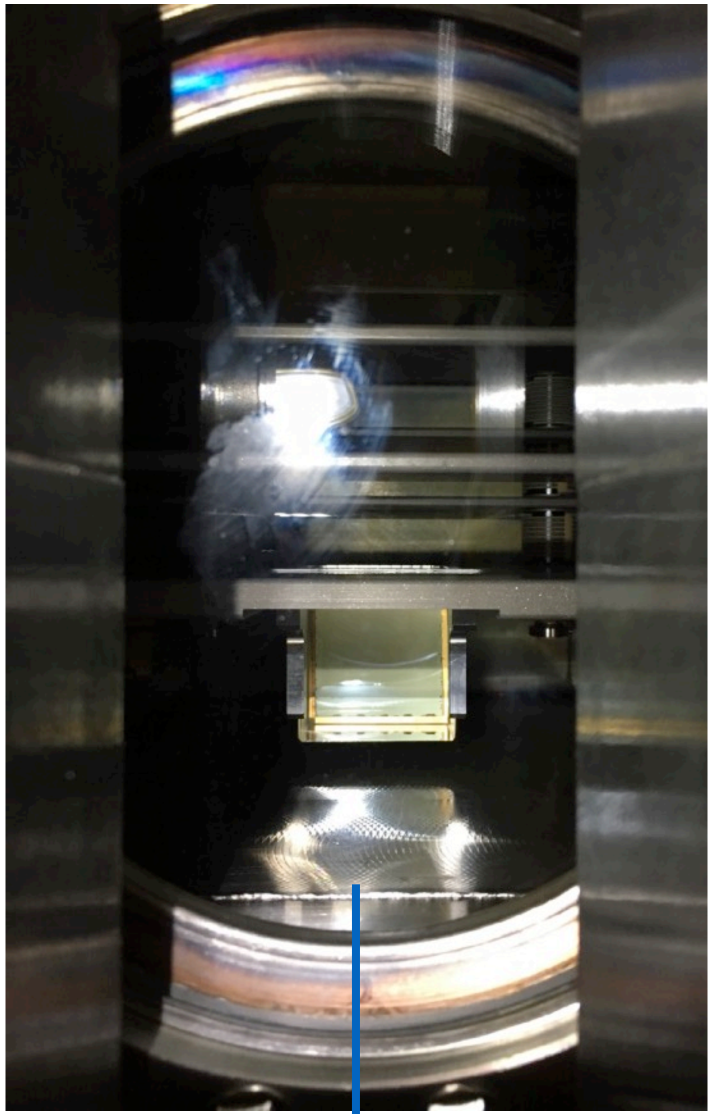
15 kV HV feedthrough

Vacuum chamber, optical system & camera.



Vacuum chamber with viewport

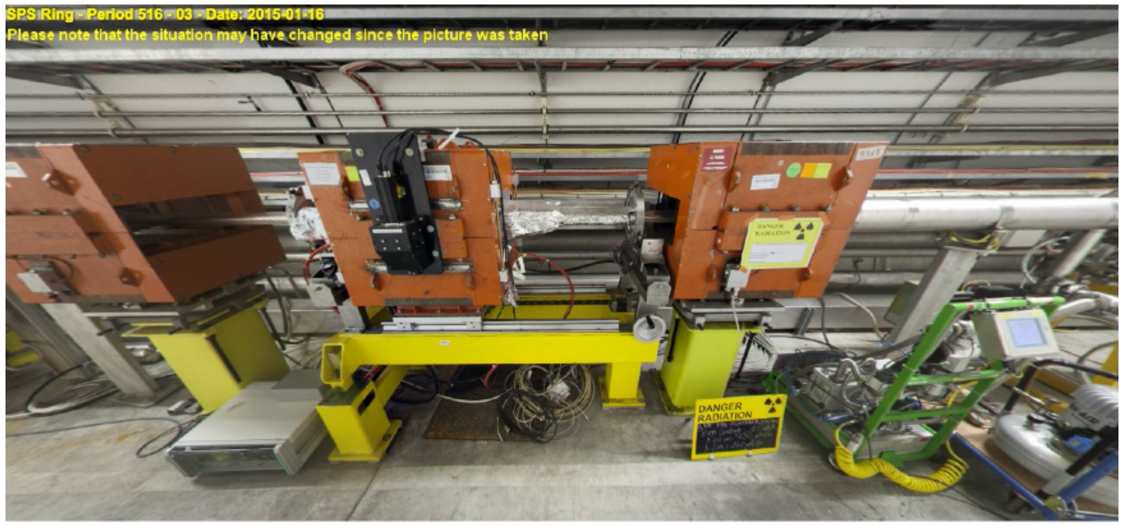
Dipole magnet (0.2T) in retracted position



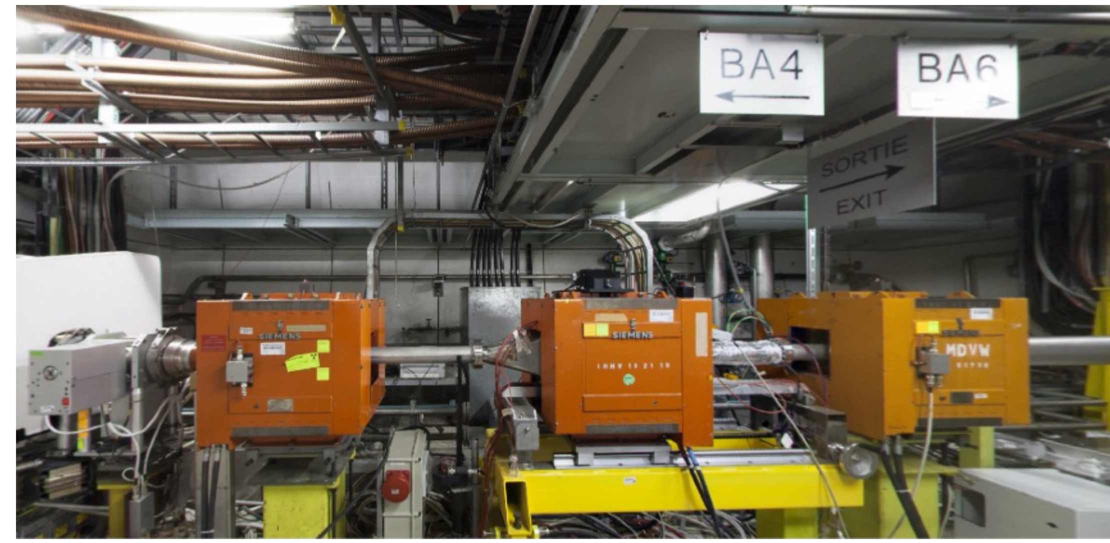
Prism viewed through opening in dipole magnet

Optical system + Thermo Fisher Scientific radiation hard (1Mrad) intensified camera (gate down to 10ns)

SPS BGI profile monitors.



BIPMH.51634 “Horizontal”



BIPMV.51734 “Vertical”

- Since 2015 same design as LHC BGI’s except no EGP calibration source.
- Dipole magnet & corrector provides 0.2 T magnetic field.

Problems encountered in 2015/2016.

Failure of Thermo Scientific intensified camera readout electronics:

- Not designed for operation in radiation environment.
- Solution: Move electronics to lower radiation areas in the tunnel & minimise time system is active by means of a remote relay.

Limited gain of Thermo Scientific intensified camera due to intensifier ageing:

- Short term fix: Replaced camera intensifier.
- Medium term: Optimise use of device to minimise degradation.
- Long term: Replace with "something else".

Same for MCP & phosphor

Failure of VME card that controls in-house HV supply:

- Solution: Now use Siemens PLC based system to control HV supply.

New common slow control & environmental monitoring system for CERN BGI's.

PLC control system based on CERN standard Siemens S7 PLC, provides reliable:

- Control & limits on high voltages.
- Remote control of relays to turn on/off:
  - Camera and camera readout boxes.
  - High voltage power supplies.
  - Video amplifiers.
- Temperature readout.
- Cooling control & status (PS BGI).

BGI PLC based slow control system

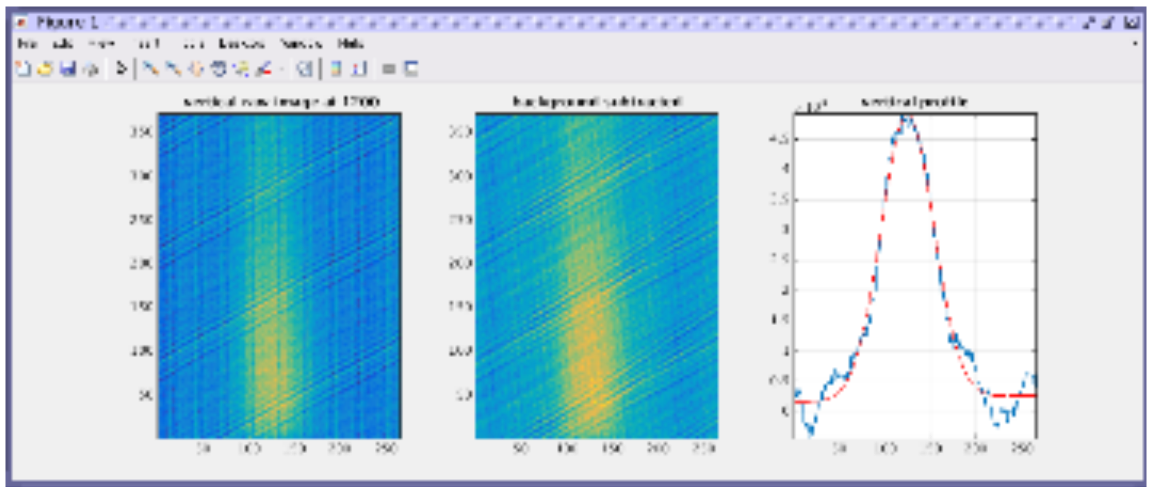
Based on SILECs (BE/CO) framework:

- Full control through SILECs C++ client interface.
- FESA classes developed.

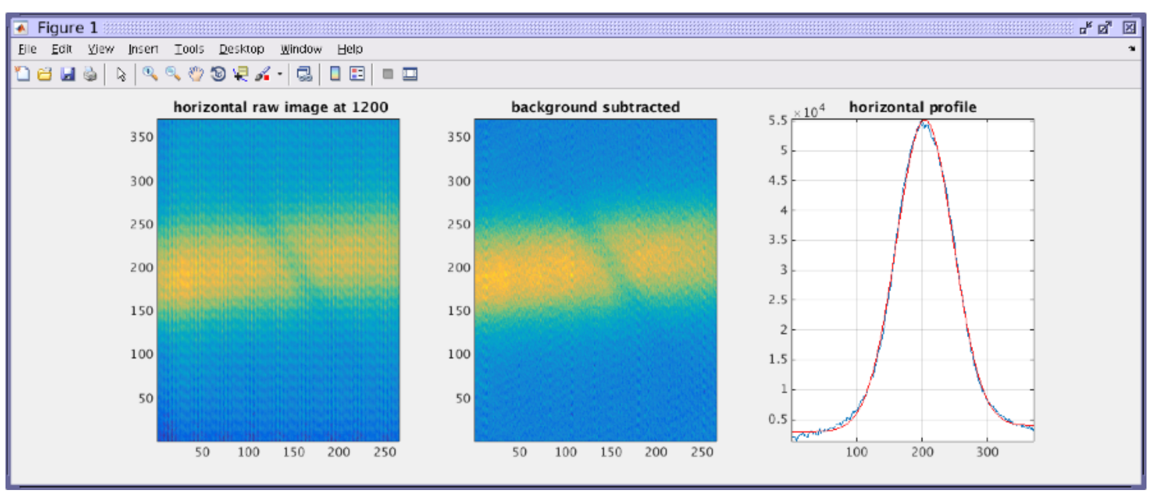
Common PLC control system used for all PS, SPS & LHC BGI's.

Summary of 2016 run.

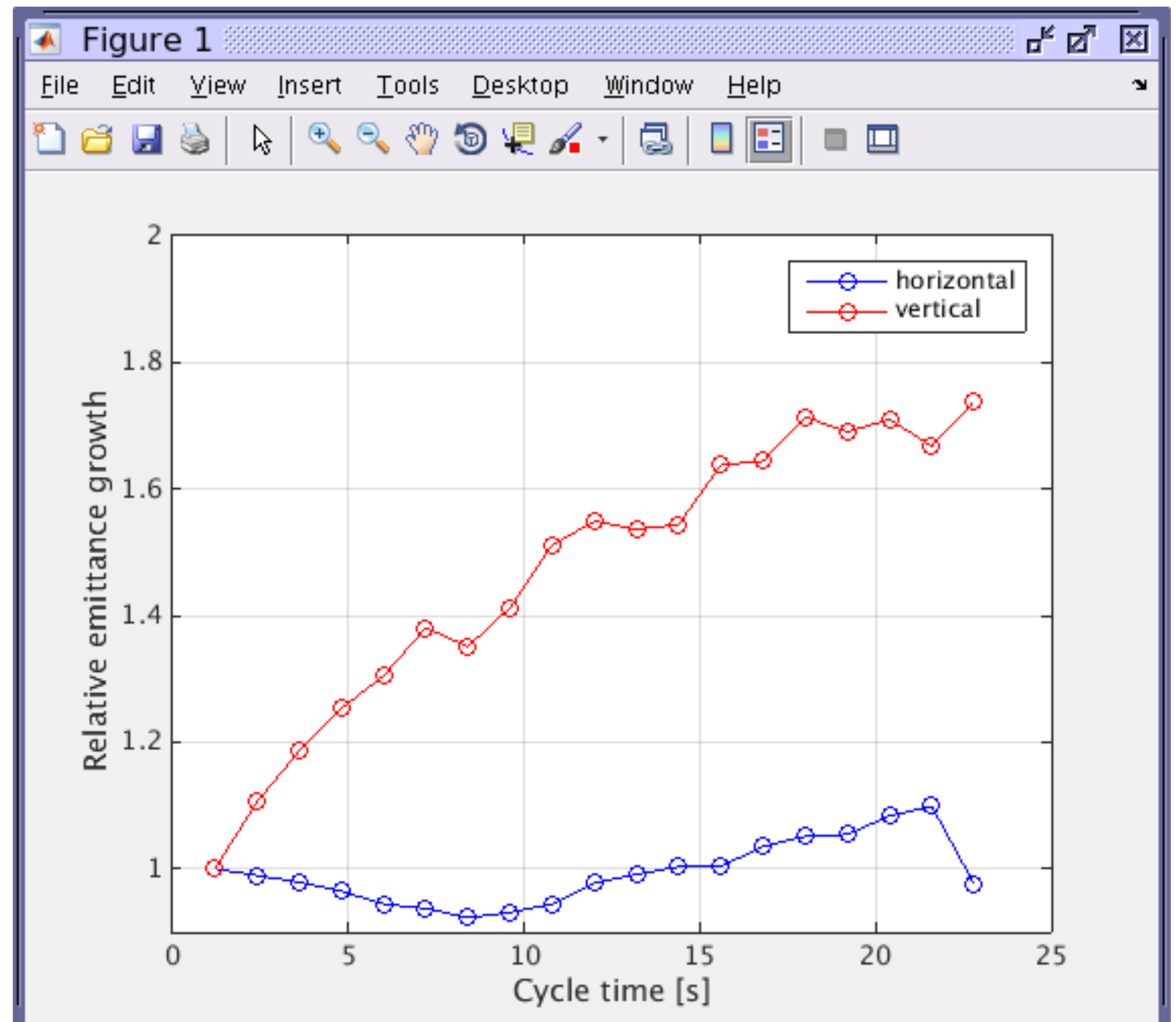
- **By the end of 2016 run reasonable signal acquired from both horizontal and vertical BGI profile monitors for low & high intensity ion and proton beams.**



Vertical BGI raw image and beam profile



Horizontal BGI raw image and beam profile



Relative vertical & horizontal emittance growth during the cycle

Figures from Hannes Bartosik and Alexander Huschauer (BE-ABP).

SPS BGI's: Summary of operational experience.

Problems encountered & solved:

- Failure of Thermo Scientific intensified camera readout electronics.
- Failure of legacy VME based HV control cards.
- Transmission of video signal.

Known limitations:

- Ageing of intensified cameras.
- Ageing of the MCP.
- Ageing of the phosphor.

Avoid these limitations with pixel detector technology

Aims for 2017:

- Establish routine operational use.

LHC BGI profile monitors.

- Motivation:
  - Ion beams (synchrotron light not available at injection energy).
  - Study emittance blow-up during the ramp for proton beams.
- 4 x BGI’s: Horizontal & Vertical for B1 + Horizontal & Vertical for B2.
- Installed in 2007/8, operated throughout Run 1.
- Not been operationally used so far in Run 2; same problems as SPS + other issues.

LHC BGI B1 Horizontal.

Same as SPS BGI’s, except:

- EGP electron calibration source.
- Neon gas injection providing 10^{-8} mbar pressure bump.

Experience from LHC Run I:
Work of M.Sapinski, D.Vilsmeier, B.Dehning.

Measured beam profile shape is deformed for very high brightness LHC beams.

Proposed solutions:

1. **Interquartile method**
   - Okay for beams sizes > 0.3 mm.

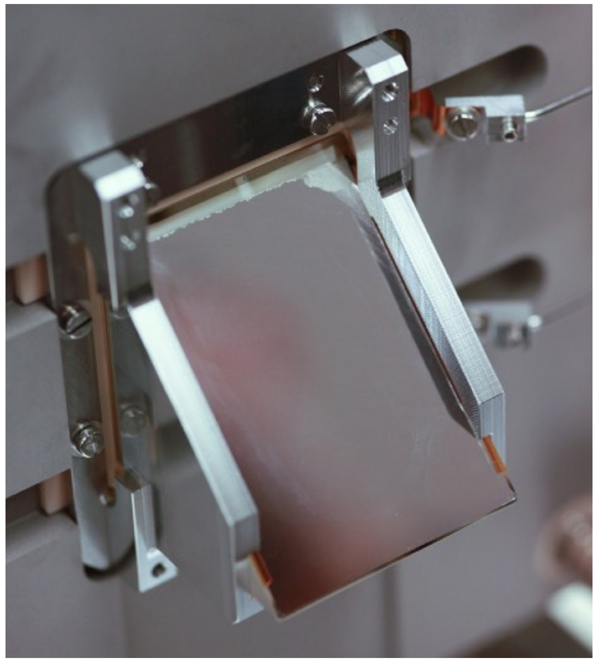
2. **Stronger magnet**
   - Need ~1T → expensive for the aperture size needed for optical based BGI.

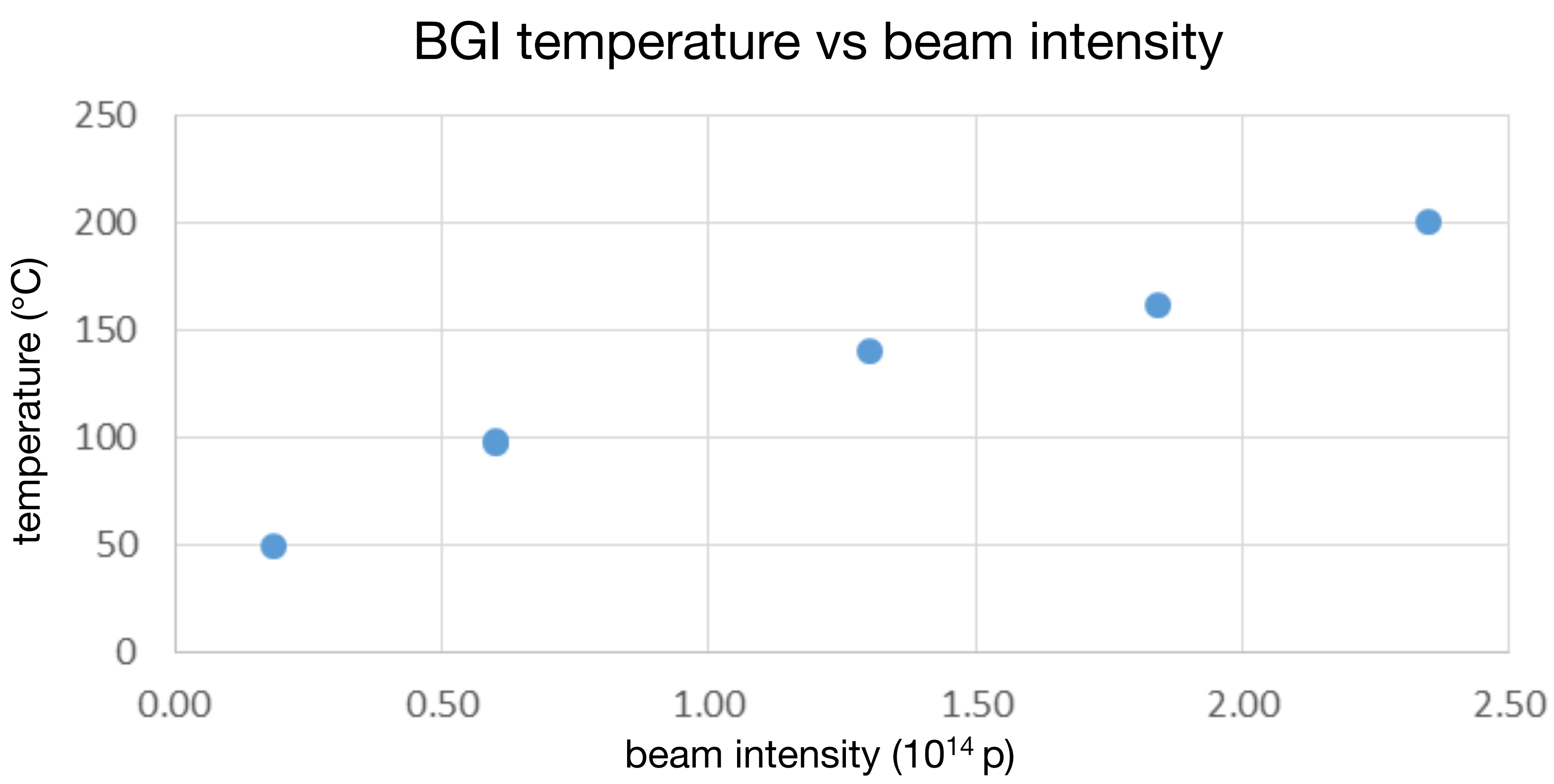
3. **Determine gyro-radius with "electron sieve"**
   - Filter above MCP with holes of various hole diameter.

Ref. http://accelconf.web.cern.ch/AccelConf/HB2014/papers/mopab42.pdf

Heating problem.

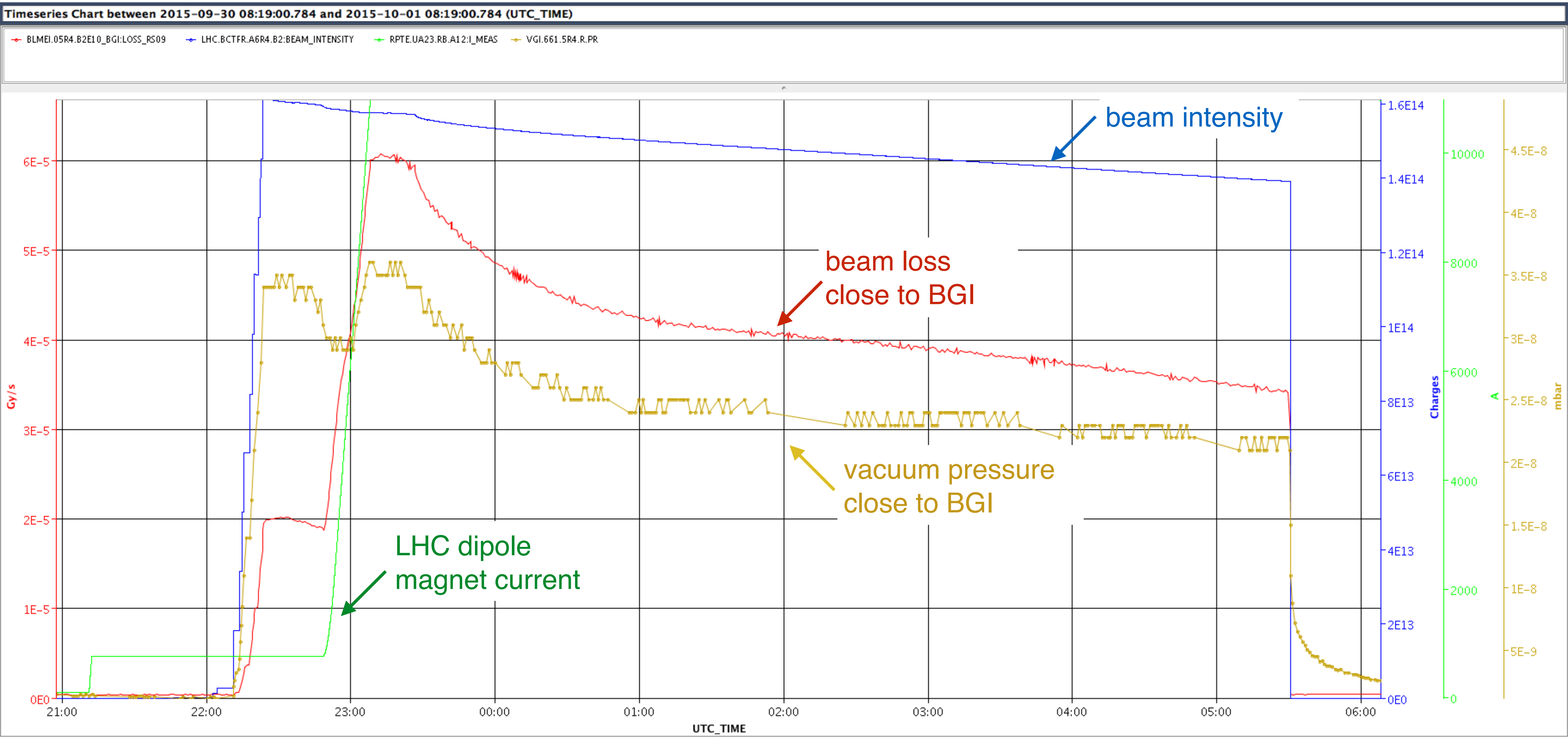
- Temperature sensor installed on prism support.
- Prism is the substrate for P46 phosphor and aluminium mirror that reflects light towards viewport.





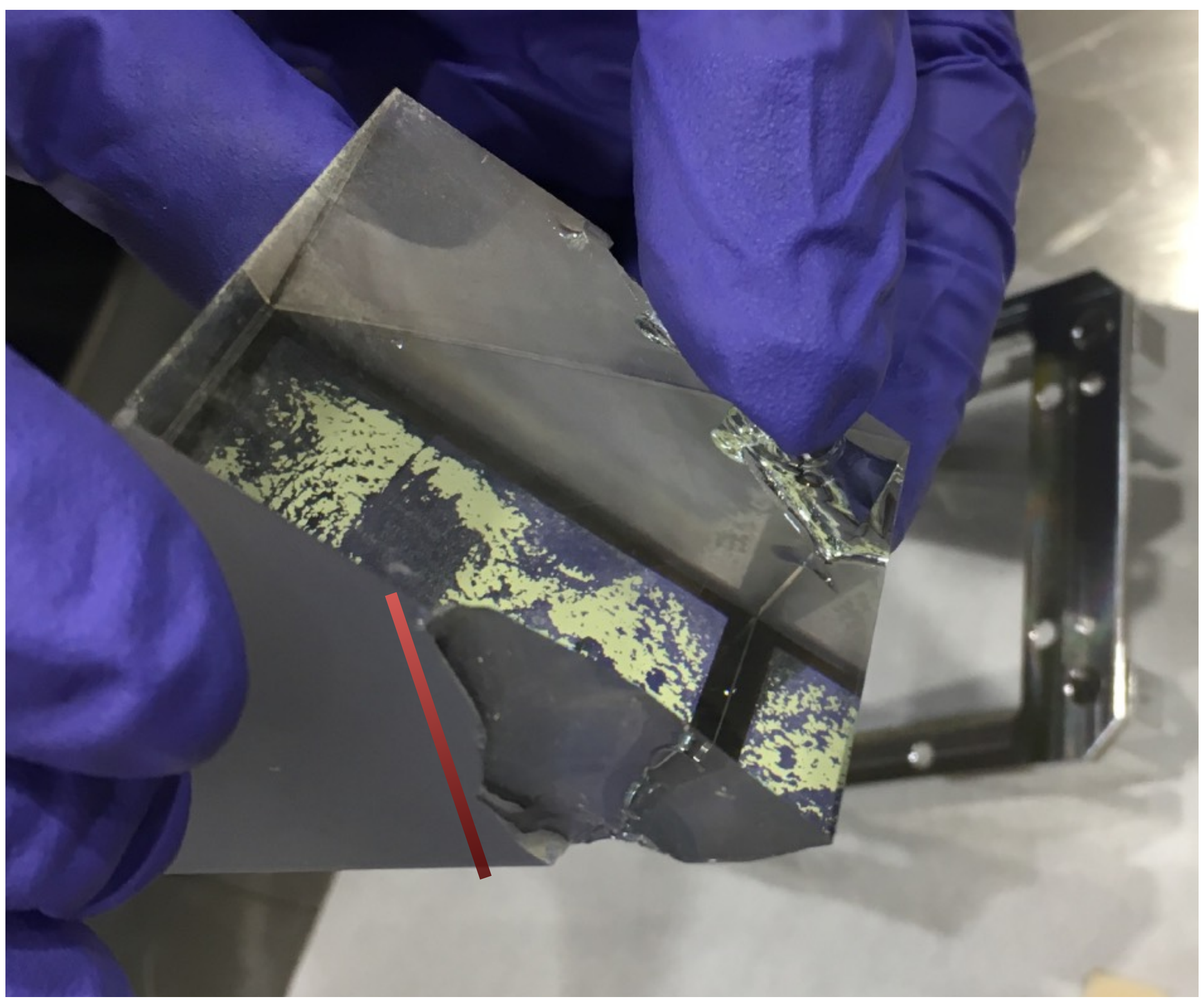
Study by Benoit Salvant (BE-ABP).

Vacuum gauge and Beam Loss Monitor (BLM) measurements close to the BGI.

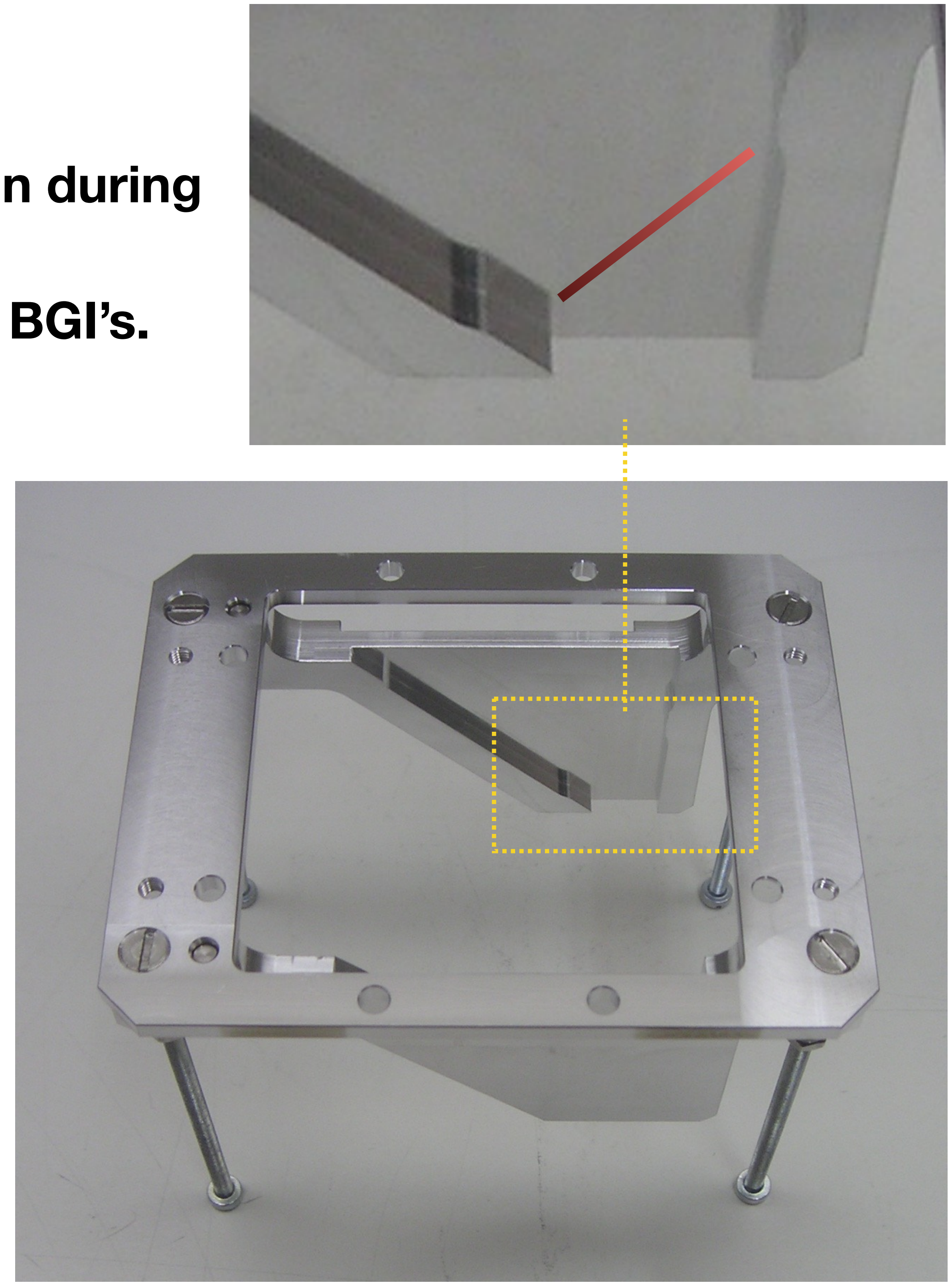


Broken prism.

- **All four LHC BGI's removed for inspection during 2016/17 winter technical stop.**
- **Fused silica prism broken on all 4 x LHC BGI's.**

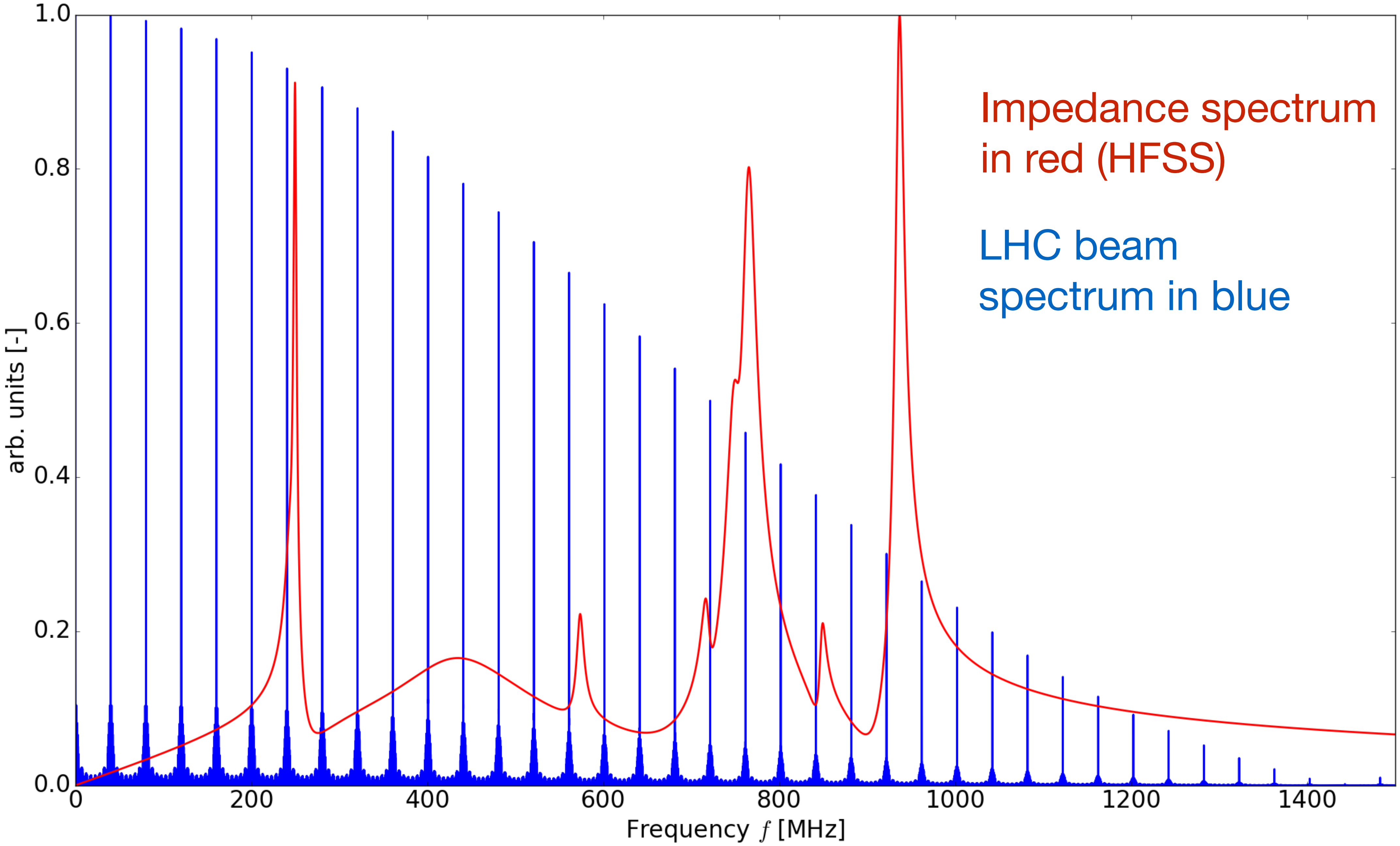


Broken fused silica prism.



Aluminium prism support.

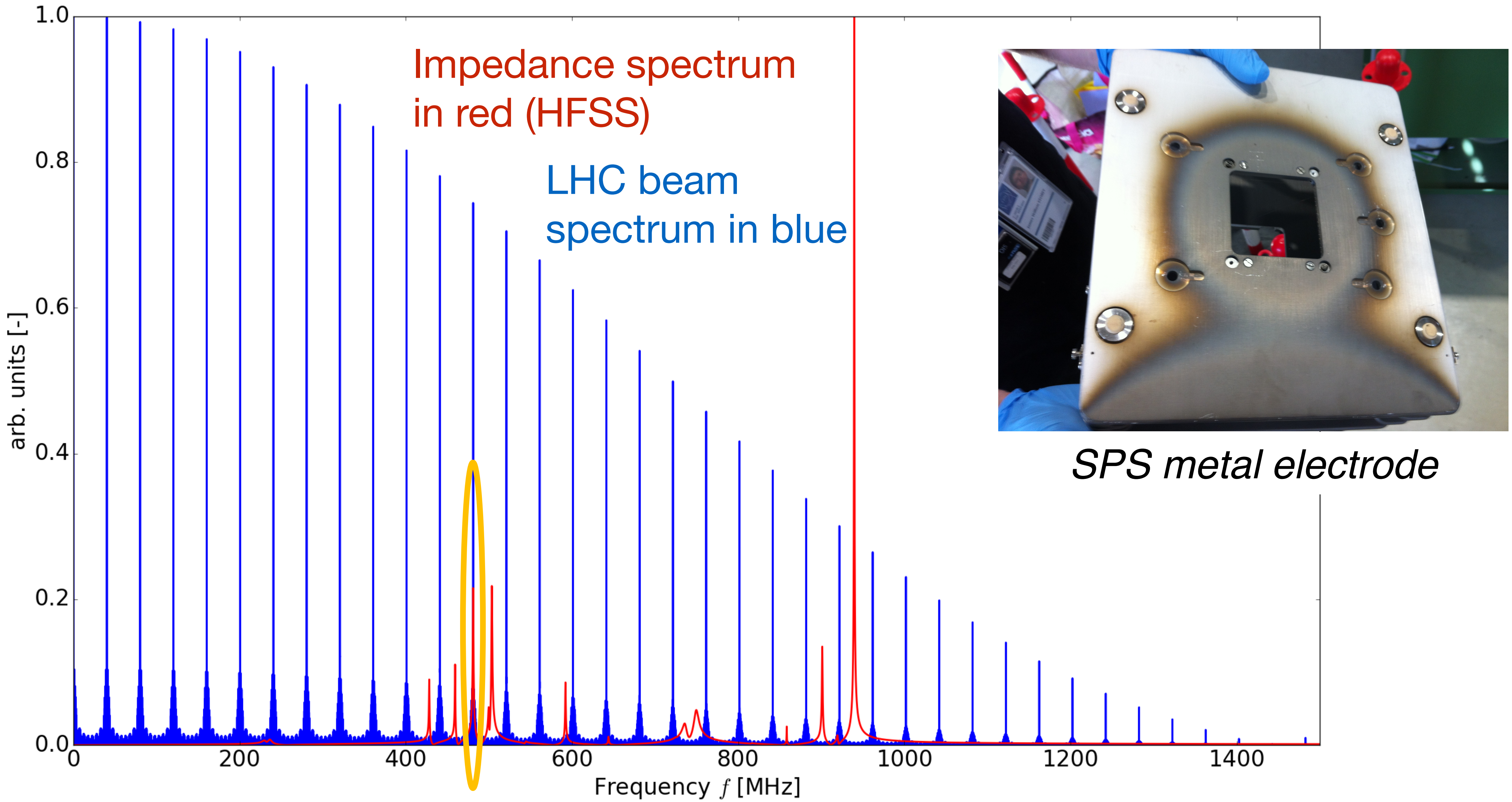
LHC BGI power loss with NEG coated electrodes.



Broadband resonances → Power loss = 53.6 W

Study by Thomas Kaltenbacher & Christine Vollinger (BE-RF).

LHC BGI power loss with metal electrodes.



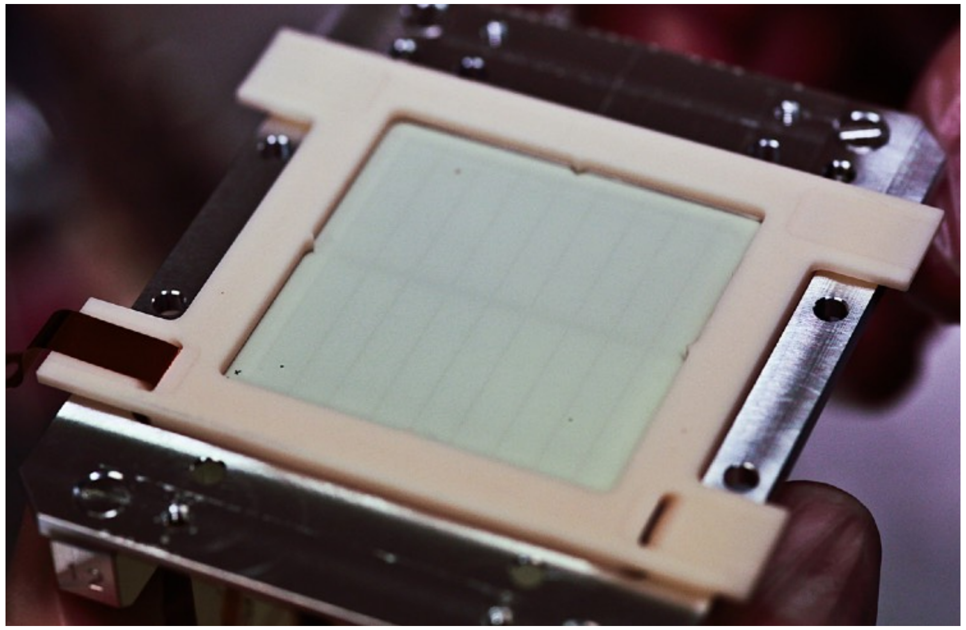
SPS metal electrode

Resonance overlap with beam harmonic at 480 MHz

→ Power loss = 205 W power loss.

Study by Thomas Kaltenbacher & Christine Vollinger (BE-RF).

Ageing of Phosphor, MCP & Intensifier.



Phosphor coating burn off.

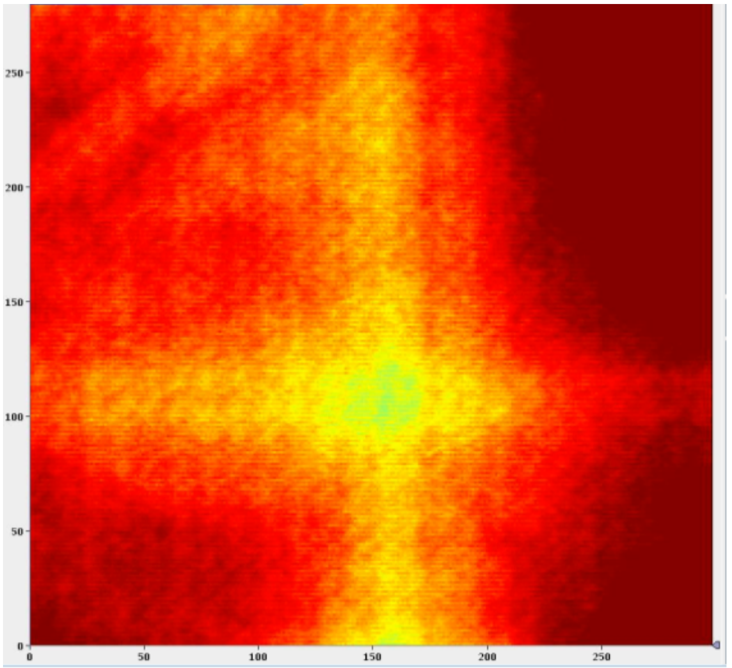
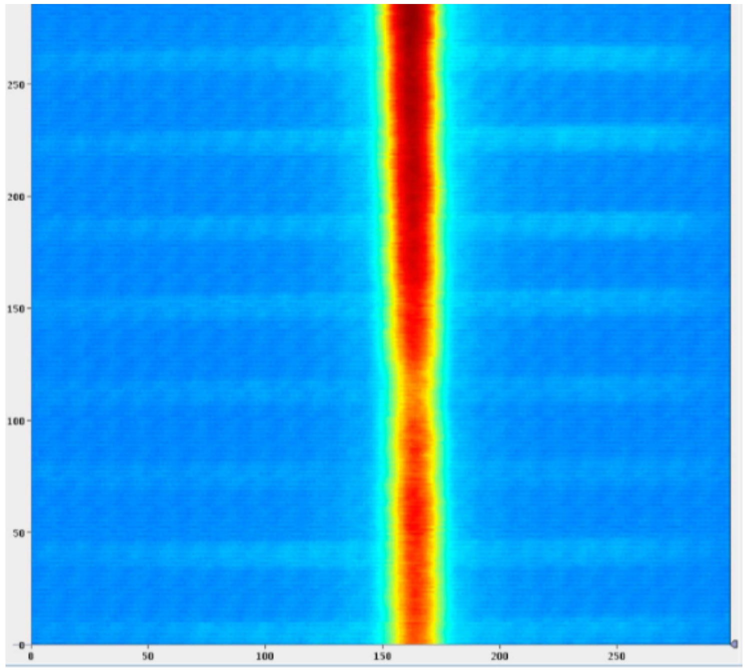


Image recorded with EGP electron source



Lead ion beam

Ageing effects observed in Phosphor, MCP and Intensifier, leads to:

- Inhomogeneous gain → Correction with EGP “standard candle”, however, EGP breaks & homogeneity of source not known.
- Lower sensitivity.

Solutions:

- Short term - optimise operational use.
- Long term - replace with “something else” (e.g. pixel detector).

Conclusion & outlook: LHC BGI's.

LHC BGI's:

- Aim to re-install LHC BGI's during 2017/18 winter shutdown.
- Source of prism heating identified:
  - Not limiting to machine operation (slight pressure rise)
    - More of an issue for detector components
  - Studying design changes to reduce power loss
    - Not obvious as this comes from cage design
- Prism breaking mechanism identified:
  - Working on redesign
- Current design okay for ion beams but operationally limited by profile broadening for proton beams:
  - Could be solved by addition of stronger magnet (~2T -> superconducting magnet)
  - Significant investment that will depend on future operational requirements.

Conclusion & outlook: SPS BGI’s.

SPS BGI’s:

- Reasonable signals acquired for both horizontal and vertical devices in 2016.
- No signs of prism heating problem.
- Aim to fulfil operational requirements this year.

Spare Slides

Original 2007 MCP / Phosphor / Prism amplifier assembly photos.