# Summary of experience with LHC and SPS IPM monitors in 2011 & 2012 (& 2013)

Mariusz Sapinski, CERN BE/BI

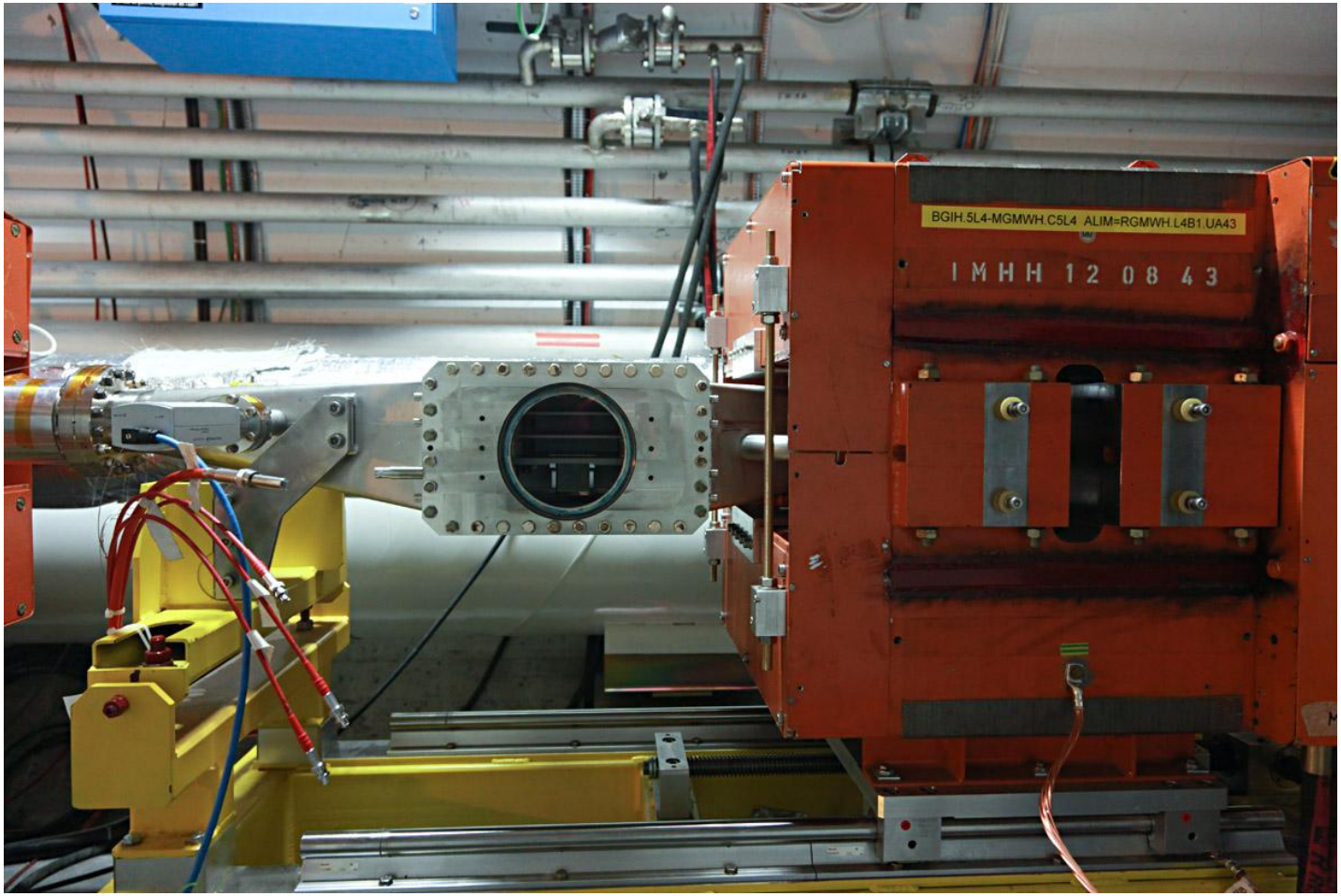
# Outlook

- High-brightness beams
- Short description of SPS and LHC IPM
  - HV
  - Gas injection
  - Magnets
  - Imaging, signal distortion (along the path)
- Hardware failures
- Calibration methods

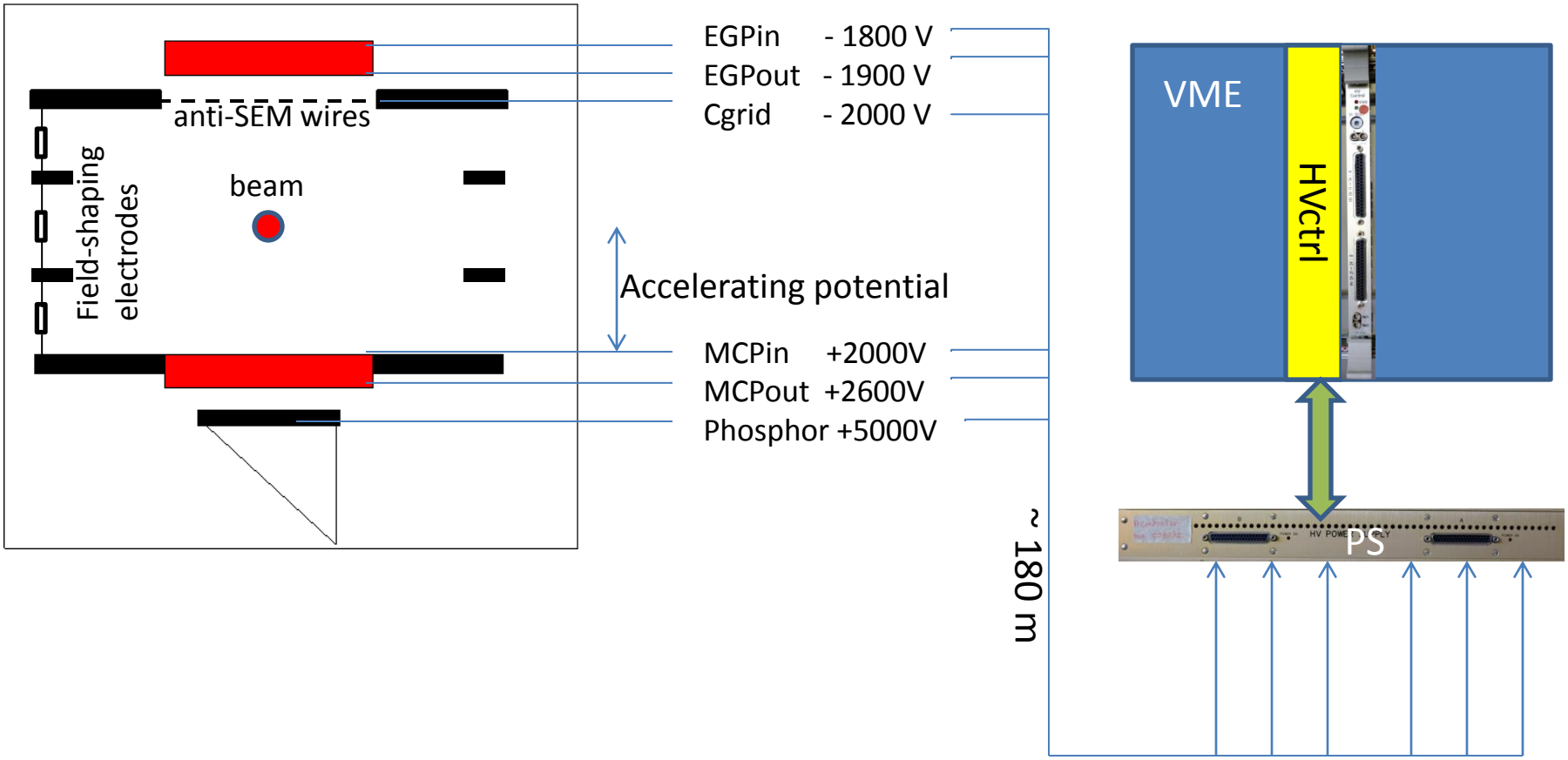
# Beams

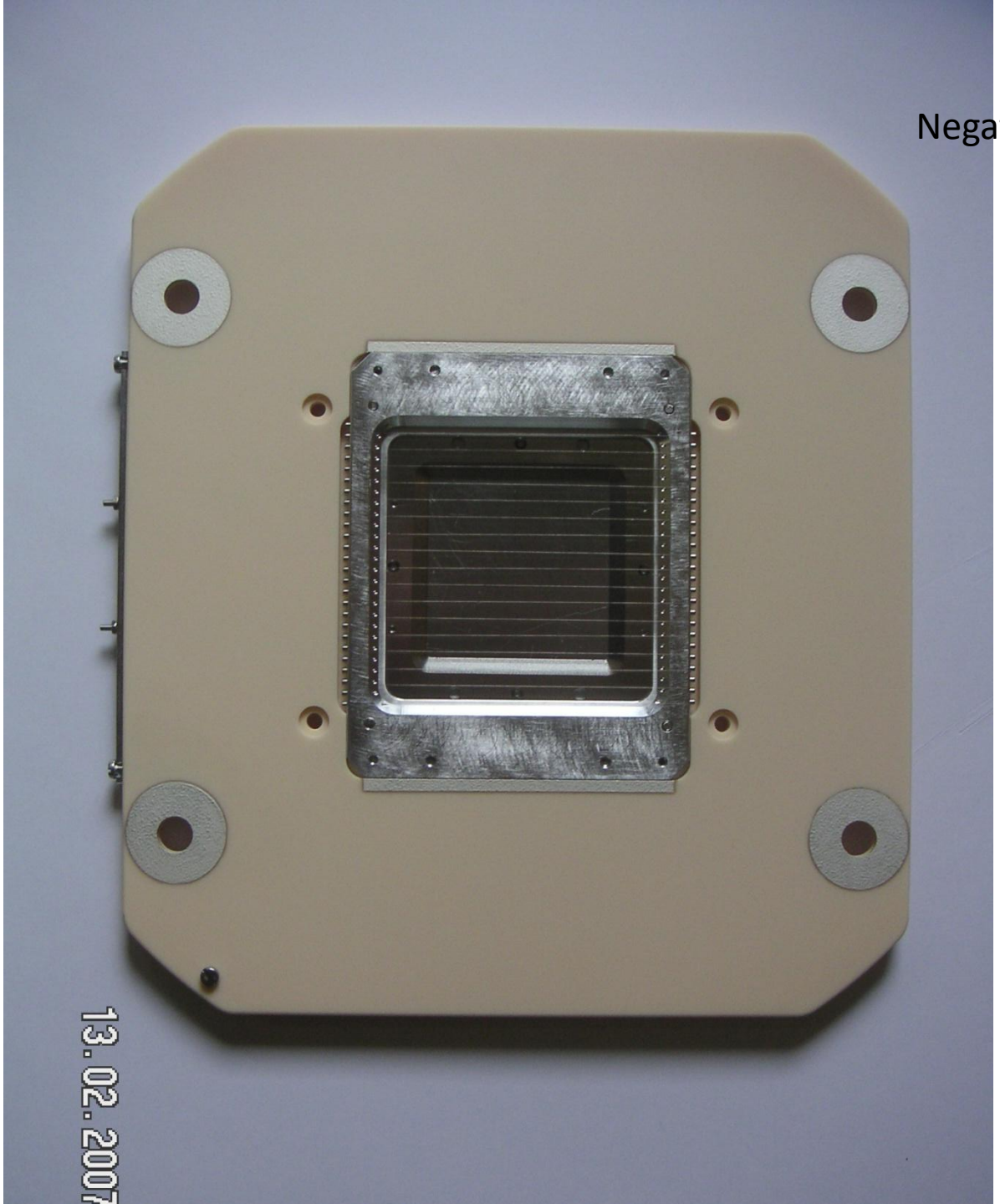
- Beams with emittance as small as 0.7 µm·rad (pPb run)
- Typical emittance for high-intensity protons: 1.5 µm·rad
- (designed emittance 3.5 µm·rad)
- Up to $1.7 \cdot 10^{11}$ protons/bunch
- Beam size: at 7 TeV, β=100 m: 100 µm
- 2800 bunches

# System: HV cage



# System: HV cage + PS + control

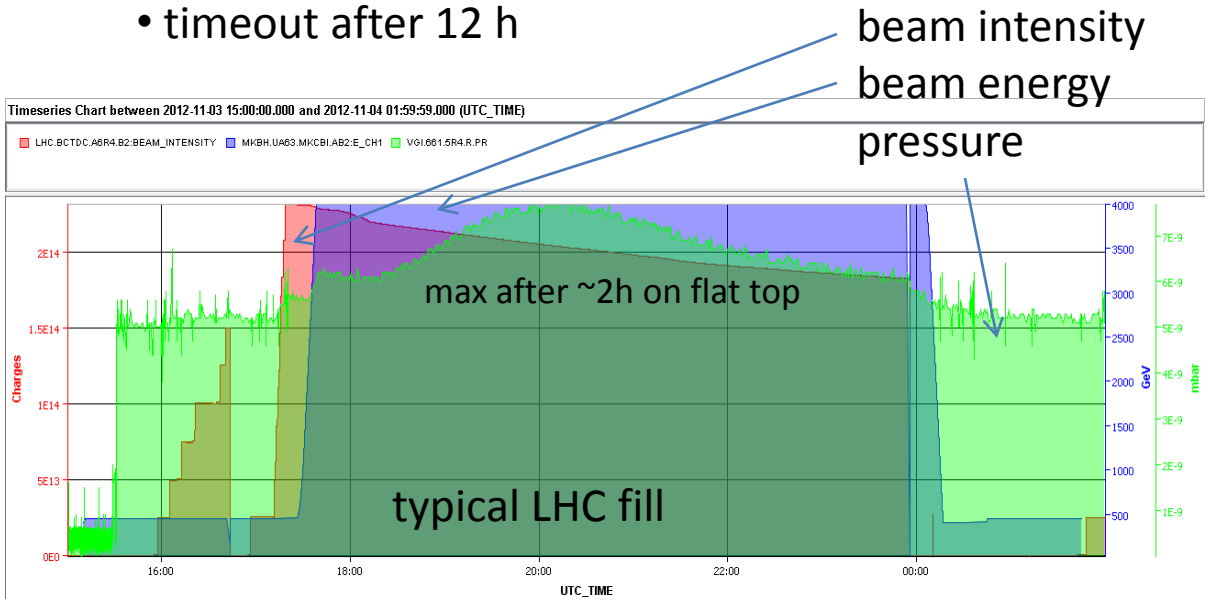


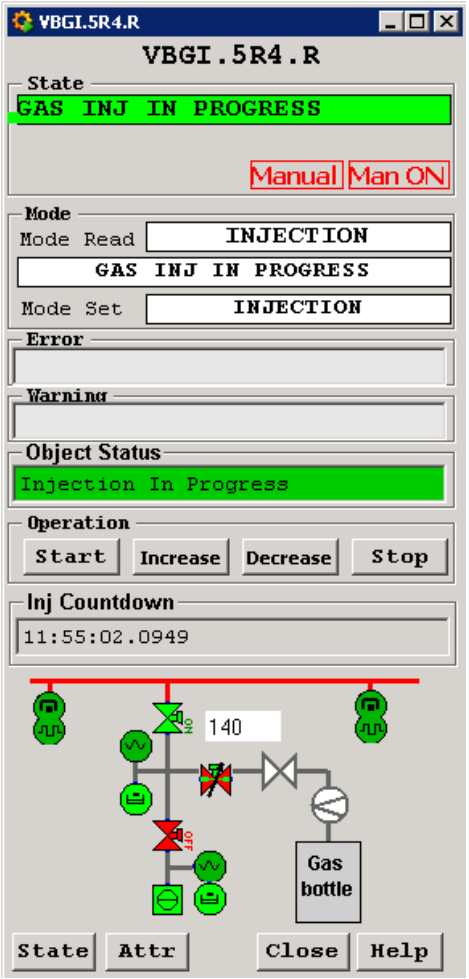



Negative electrode

# System: gas injection

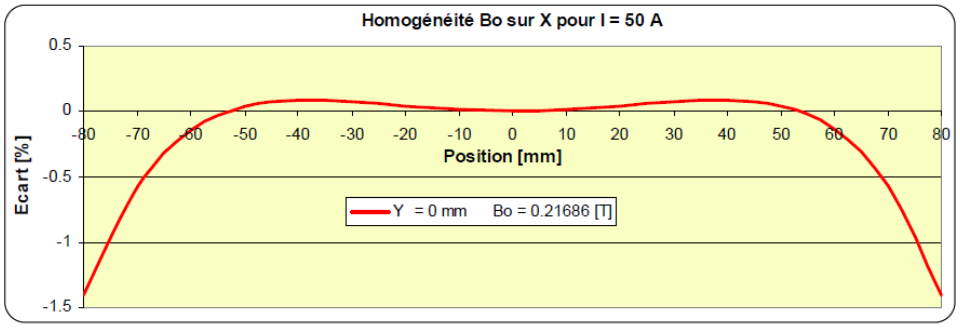
- needed in LHC (normal vacuum $10^{-11}$ mbar)
- gas injection up to $10^{-8}$ mbar
- PVSS application
- manual control (3-4 steps)
- timeout after 12 h



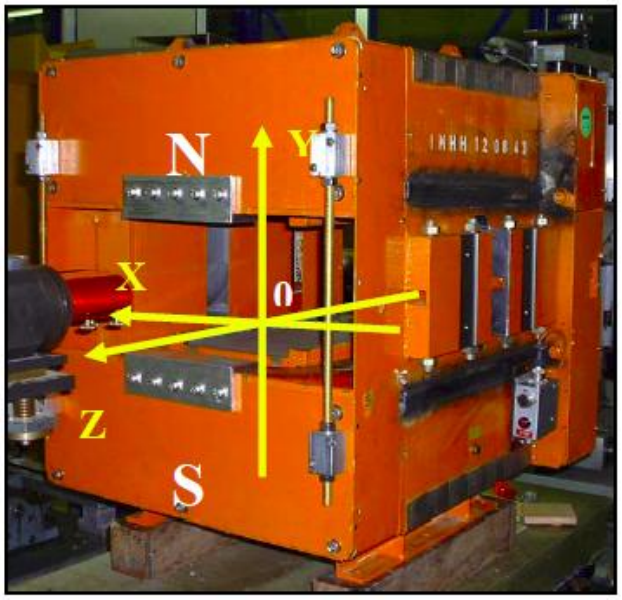



# System: magnetic field

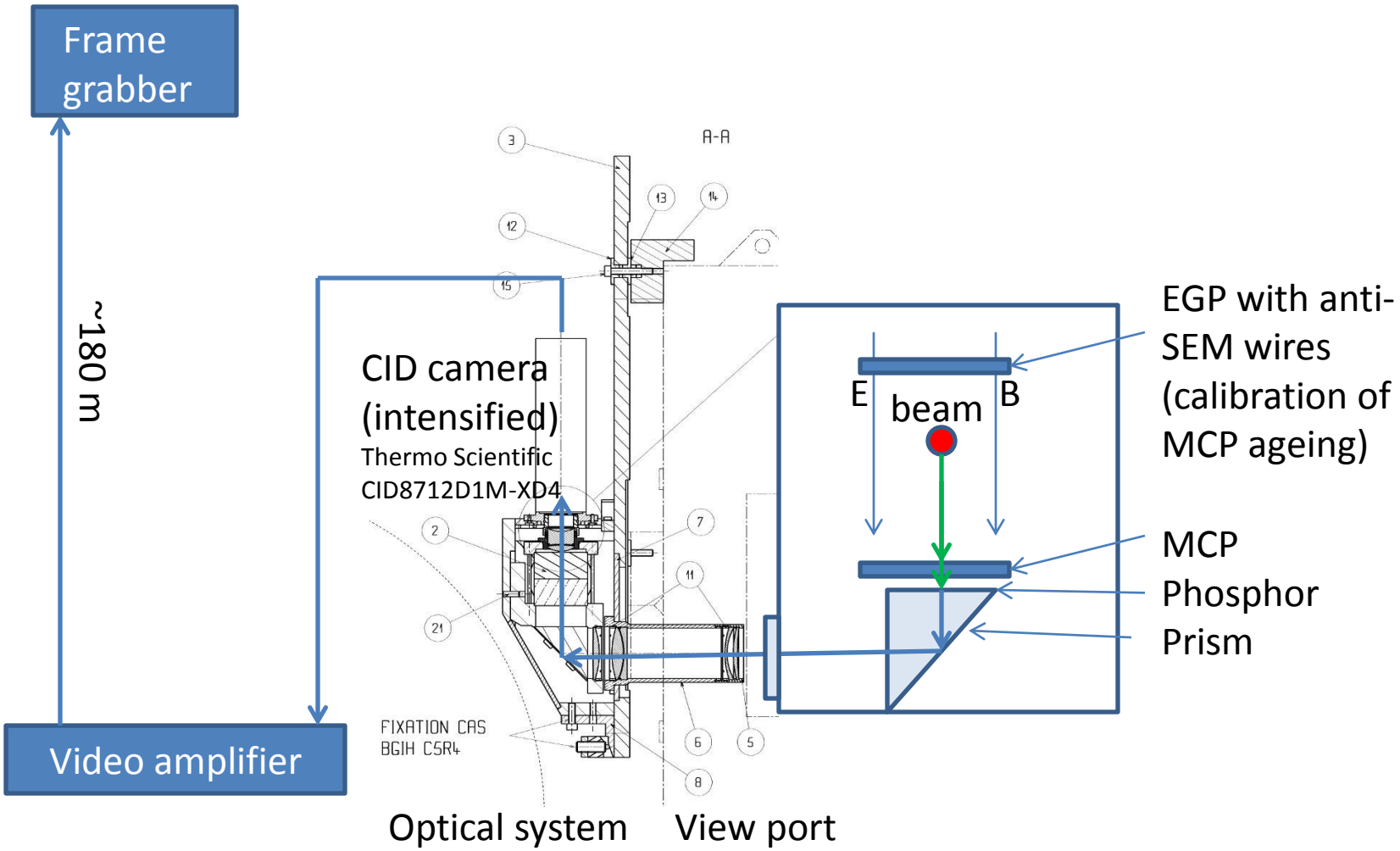
- Magnetic field needed to keep minimize beam space charge effect
- 0.2 T magnets originally from ISR, yoke modified to extract light
- Need to exchange  power converters on SPS magnets  to allow cycling.
- magnets are compensated (ie. 2 magnets/detector/plane in the same circuit)
- length 43 cm
- 20 cm space between poles
- Field quality:




Aimant type IMHH



# System: imaging



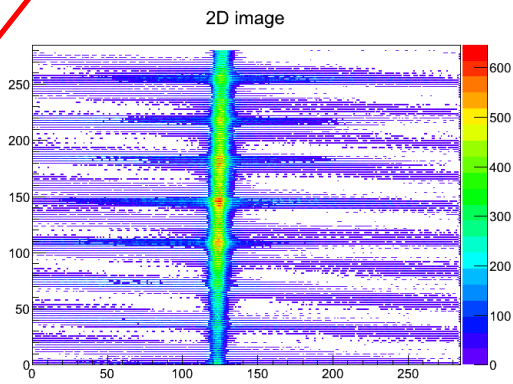
# Signal distortion

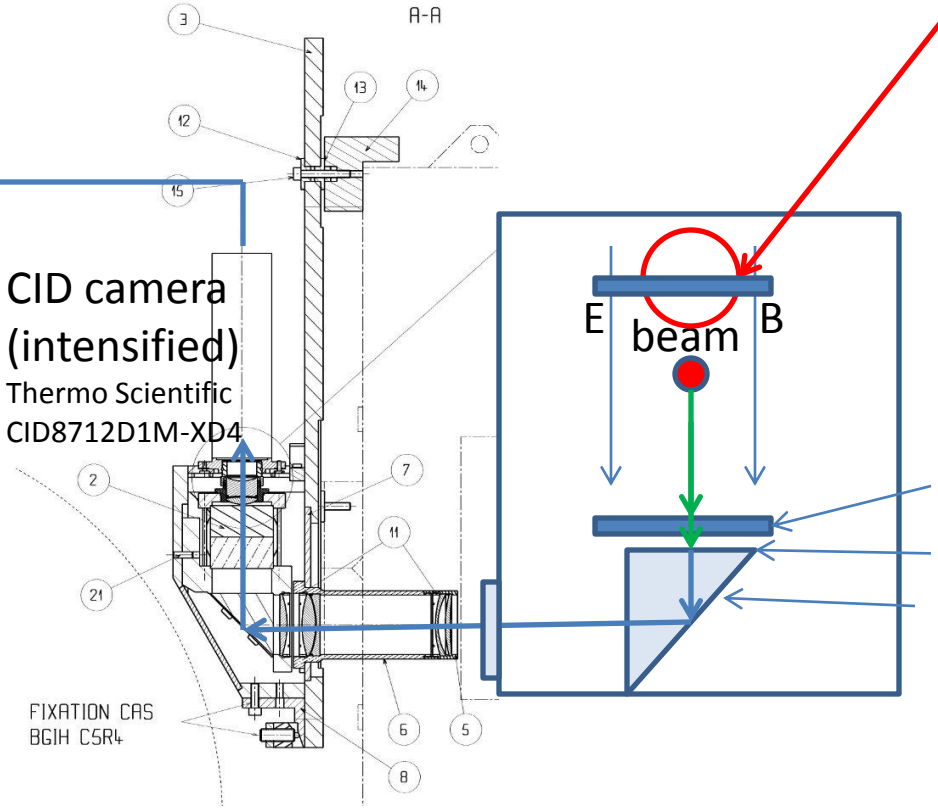
Frame grabber

~180 m

Video amplifier

Anti-SEM wires glowing:



# Signal distortion

Frame grabber

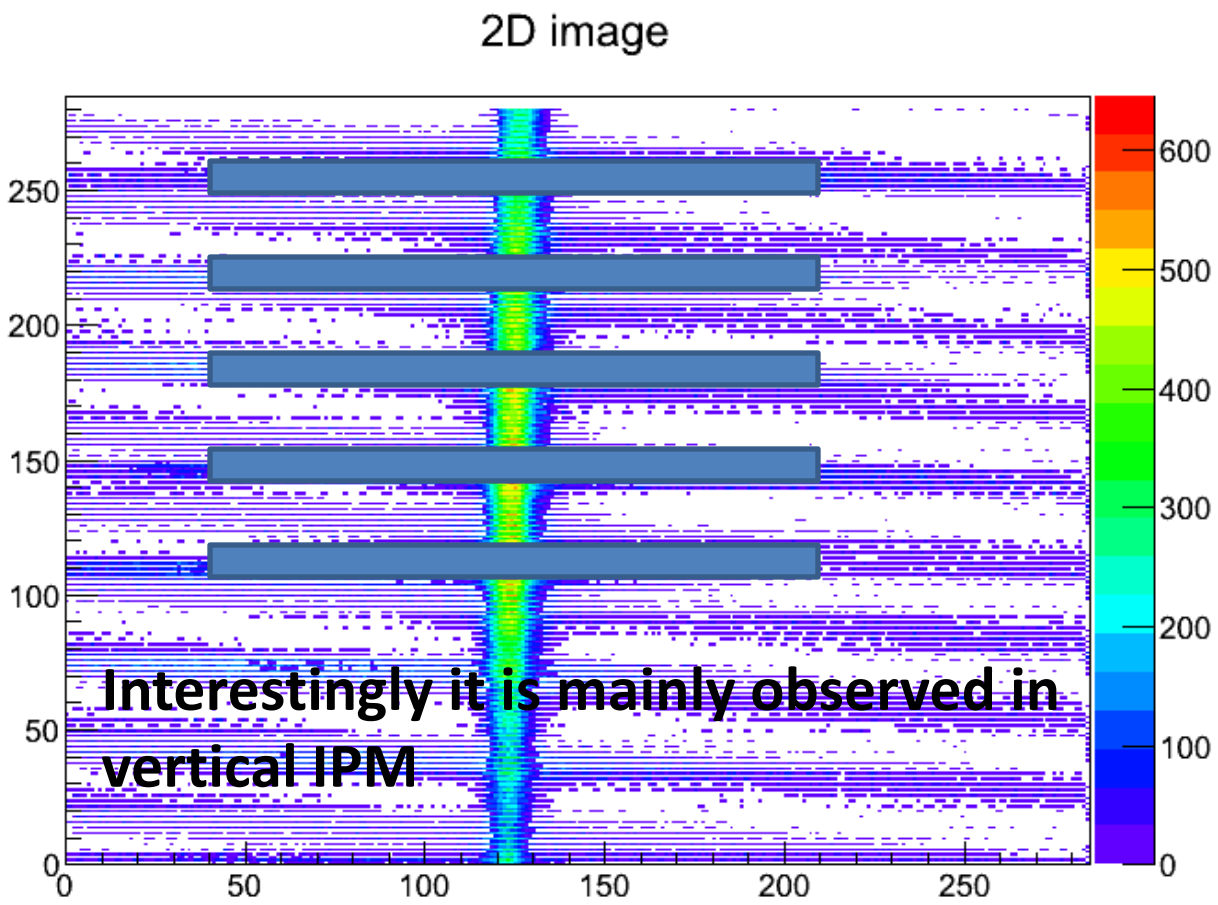
~180 m

CID cam
(intensif
Thermo Scie
CID8712D1M

Video amplifier

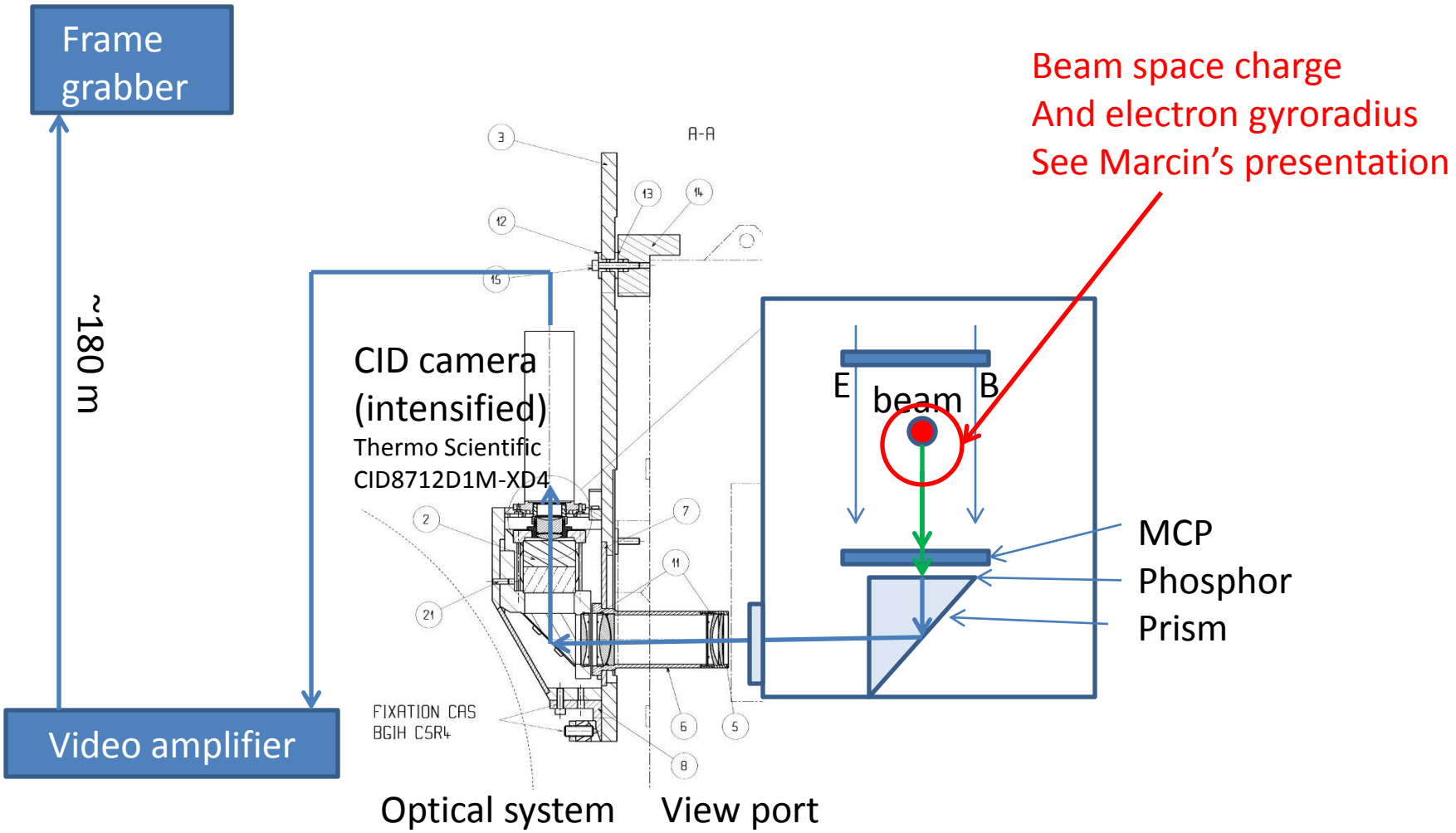
Optica

**Solution: masking at level of image processing**




**Interestingly it is mainly observed in vertical IPM**

# Signal distortion



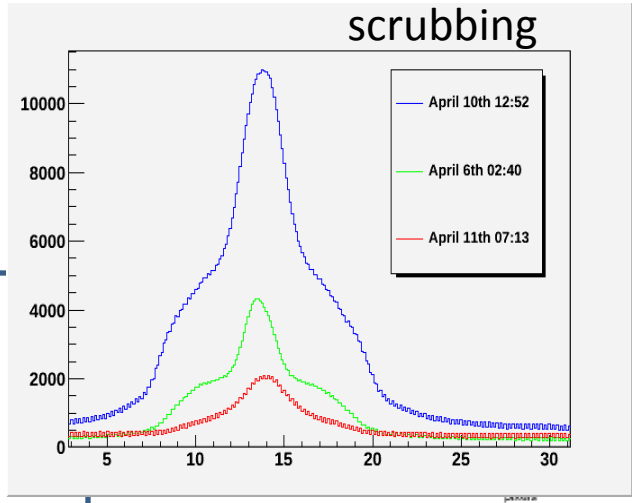
# Signal distortion

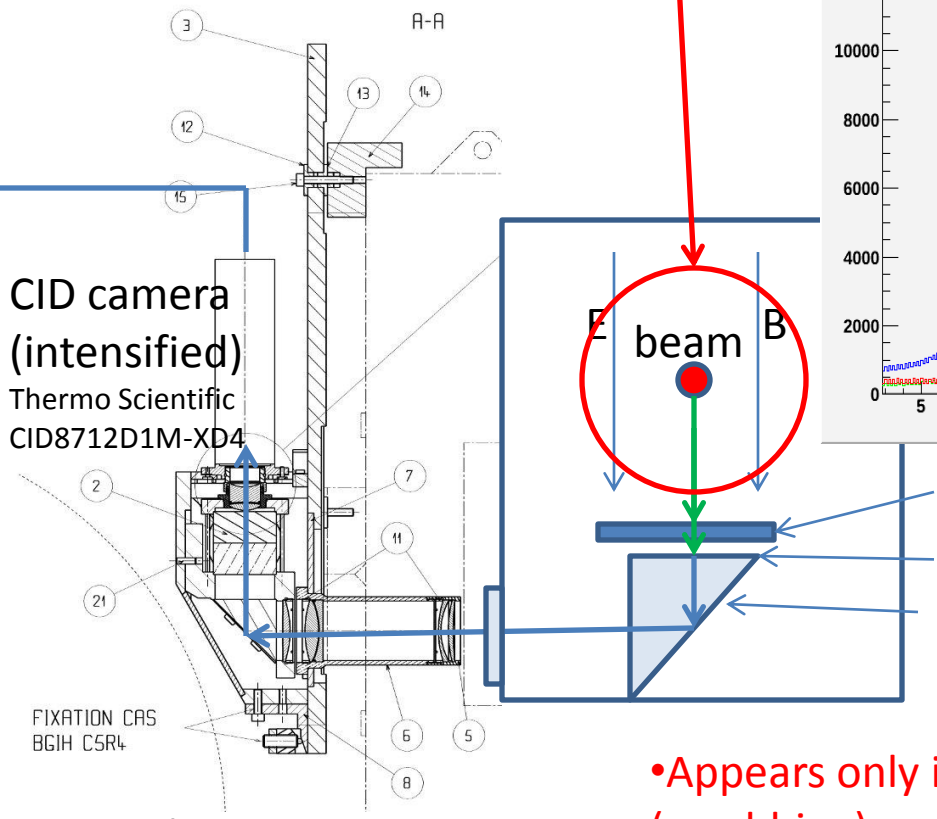
Frame grabber

~180 m

Video amplifier

Electron cloud (suspected)




CID camera (intensified)
Thermo Scientific
CID8712D1M-XD4

E beam B

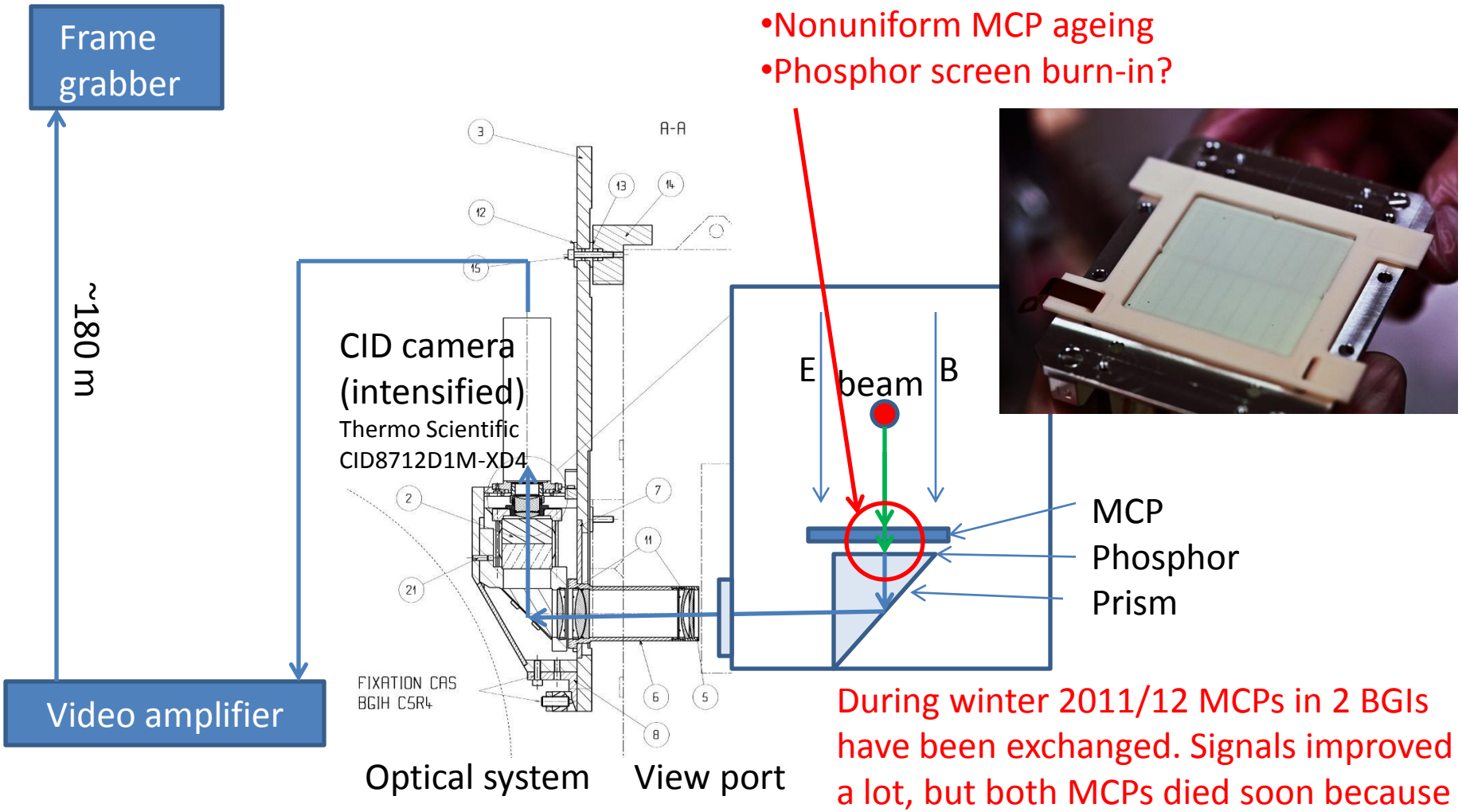
MCP
Phosphor
Prism

Optical system

View port

- Appears only in specific conditions (scrubbing).
- electrodes and MCPs are NEG-coated to suppress e-cloud

# Signal distortion




•Nonuniform MCP ageing
•Phosphor screen burn-in?



During winter 2011/12 MCPs in 2 BGIs have been exchanged. Signals improved a lot, but both MCPs died soon because of HV/high signal problems.

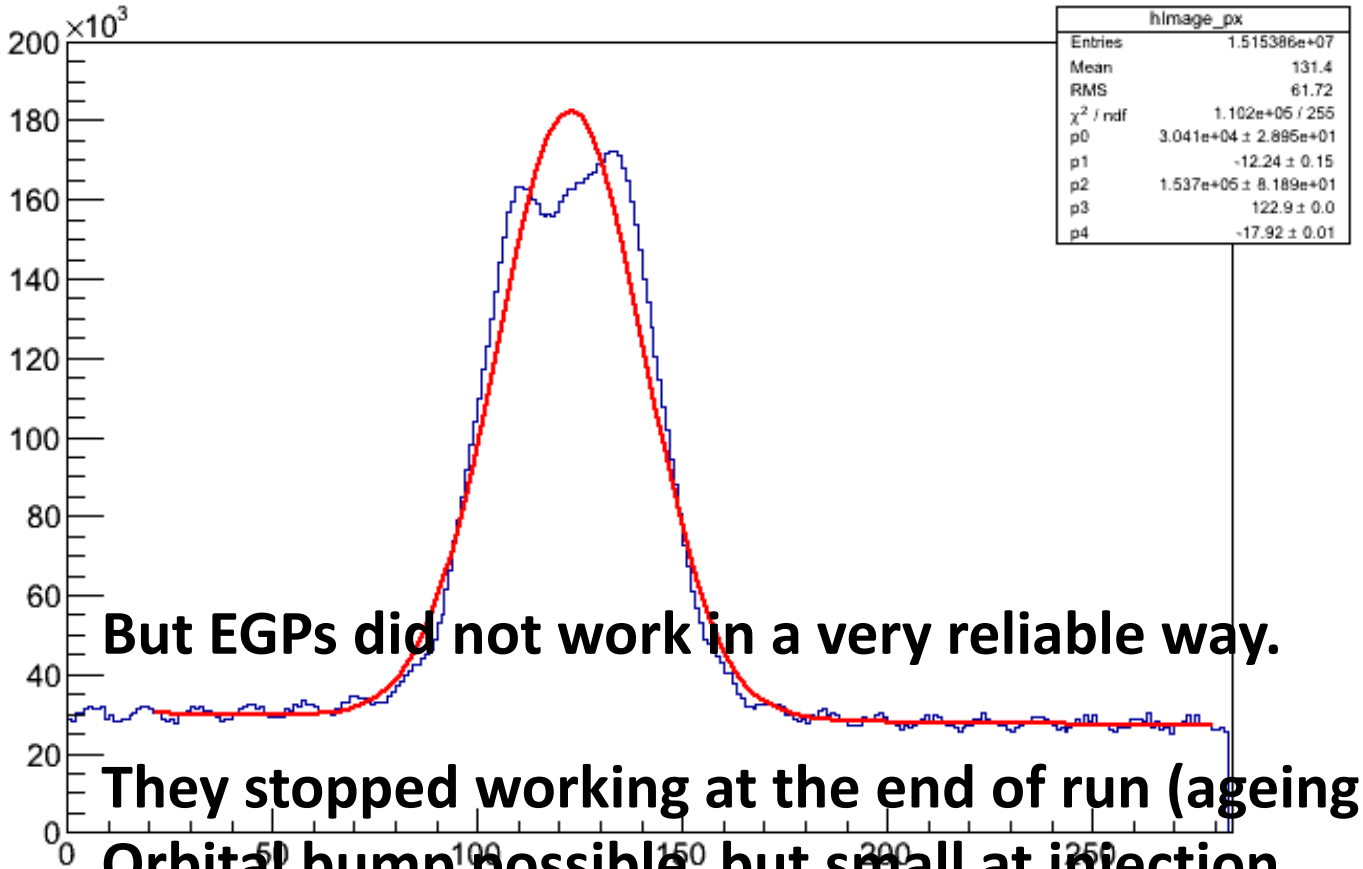
# Signal distortion

Frame grabber

~180 m

Video amplifie

**Solution: use EGP to measure nonuniformity and correct for it.**



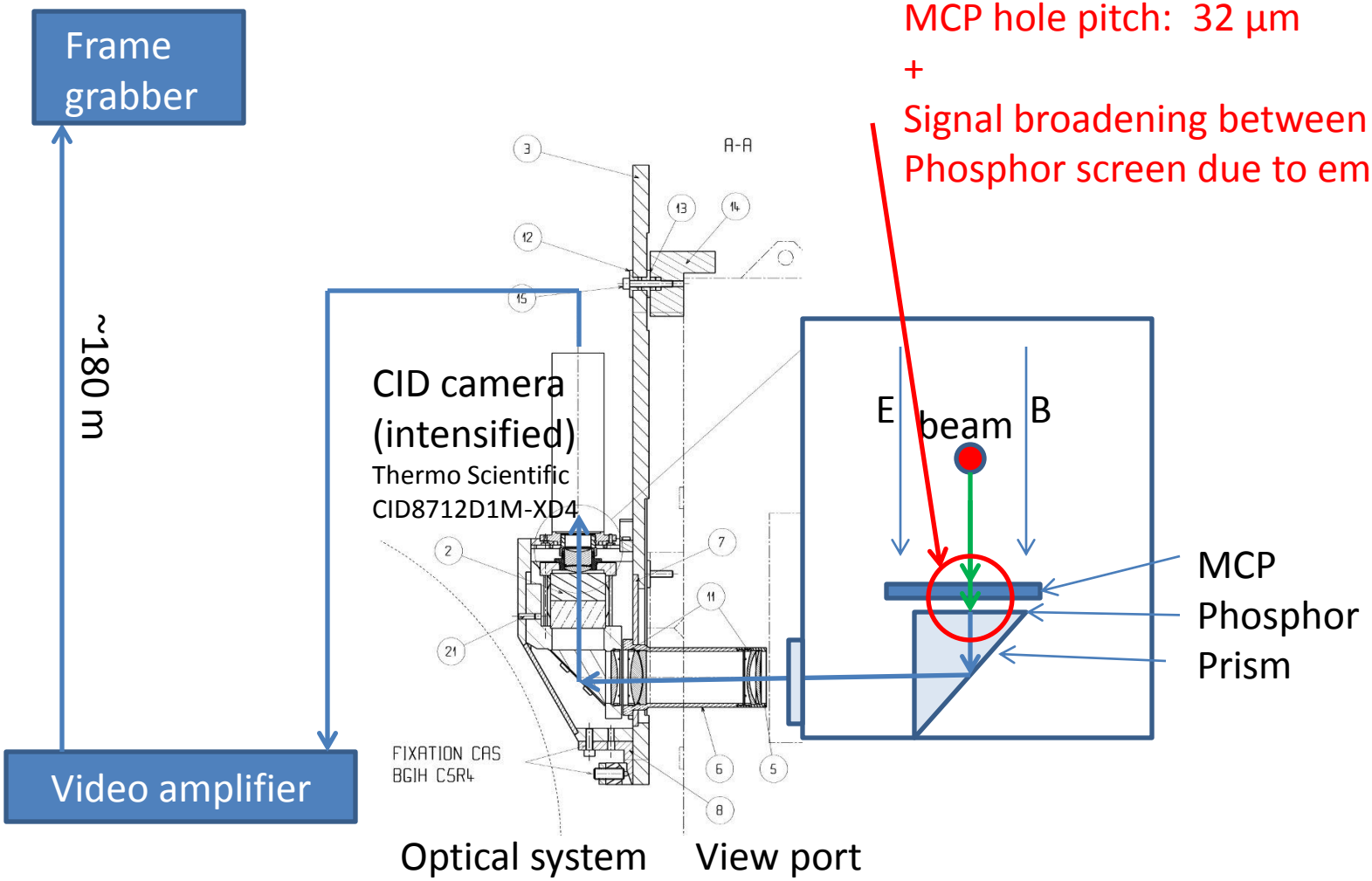

**But EGPs did not work in a very reliable way.**

**They stopped working at the end of run (ageing?)**

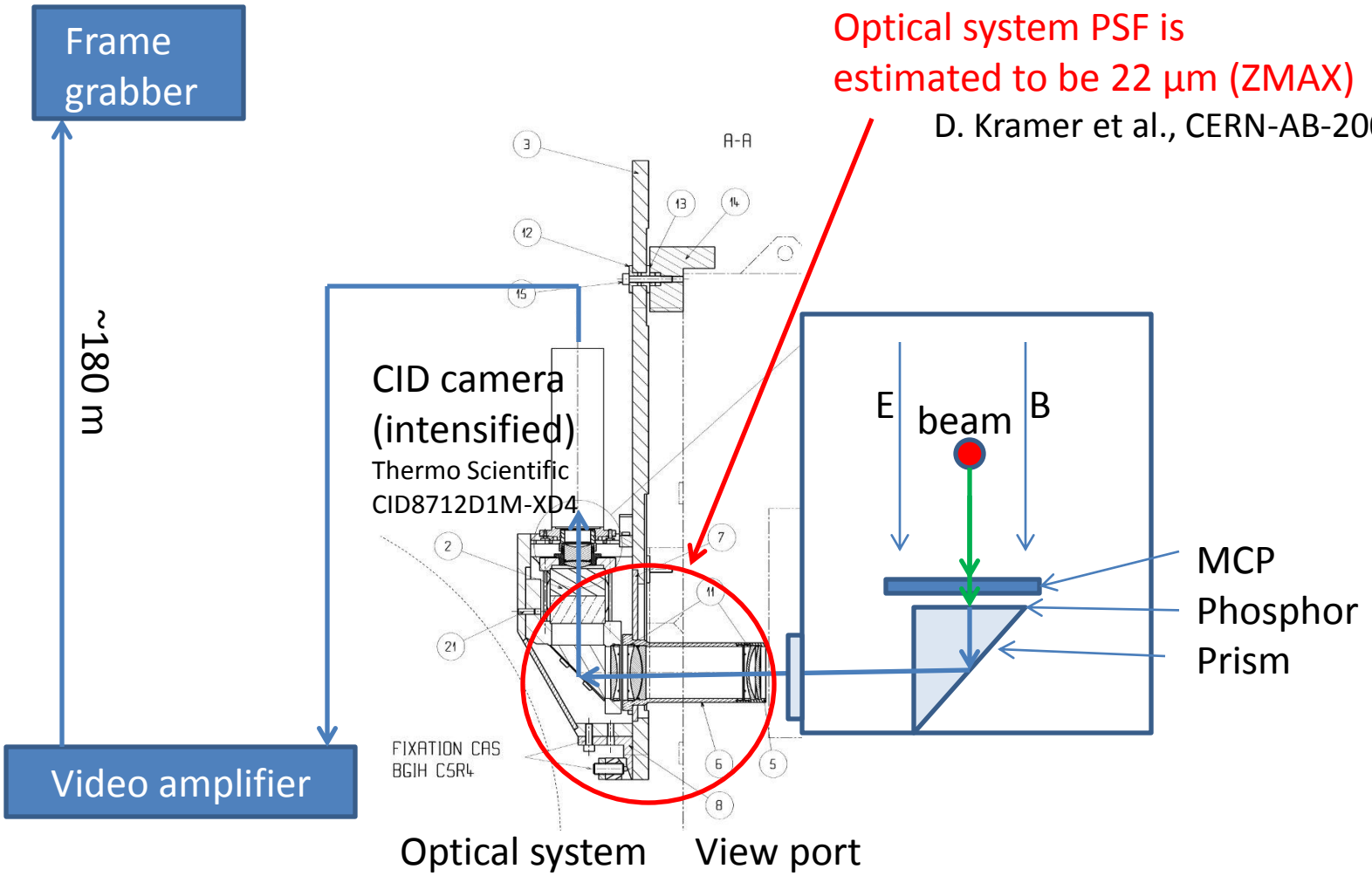
**Orbital bump possible, but small at injection.**

# Signal distortion

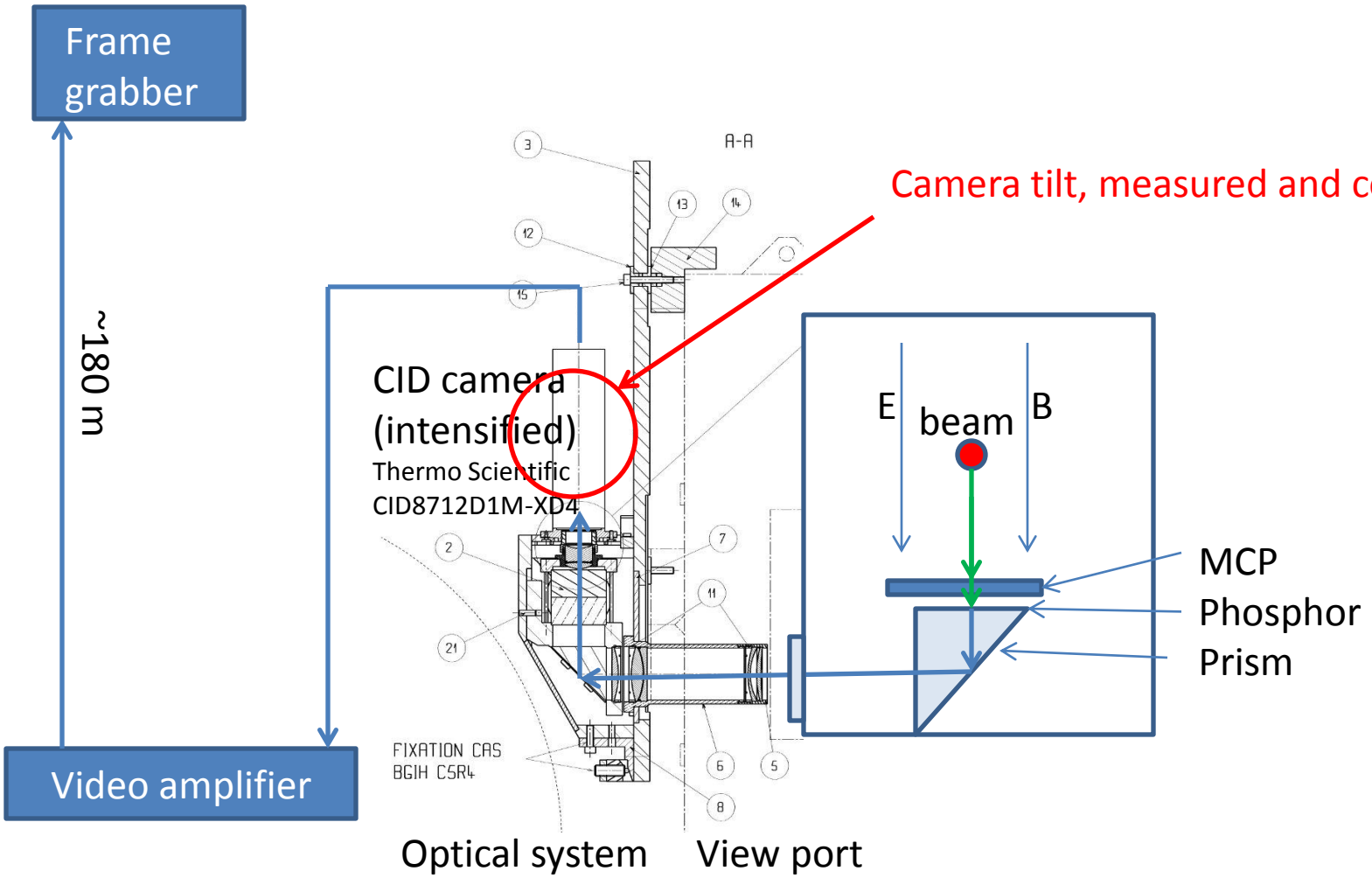
MCP hole pitch: 32 µm
+
Signal broadening between MCP and Phosphor screen due to emission cone.



# Signal distortion



# Signal distortion



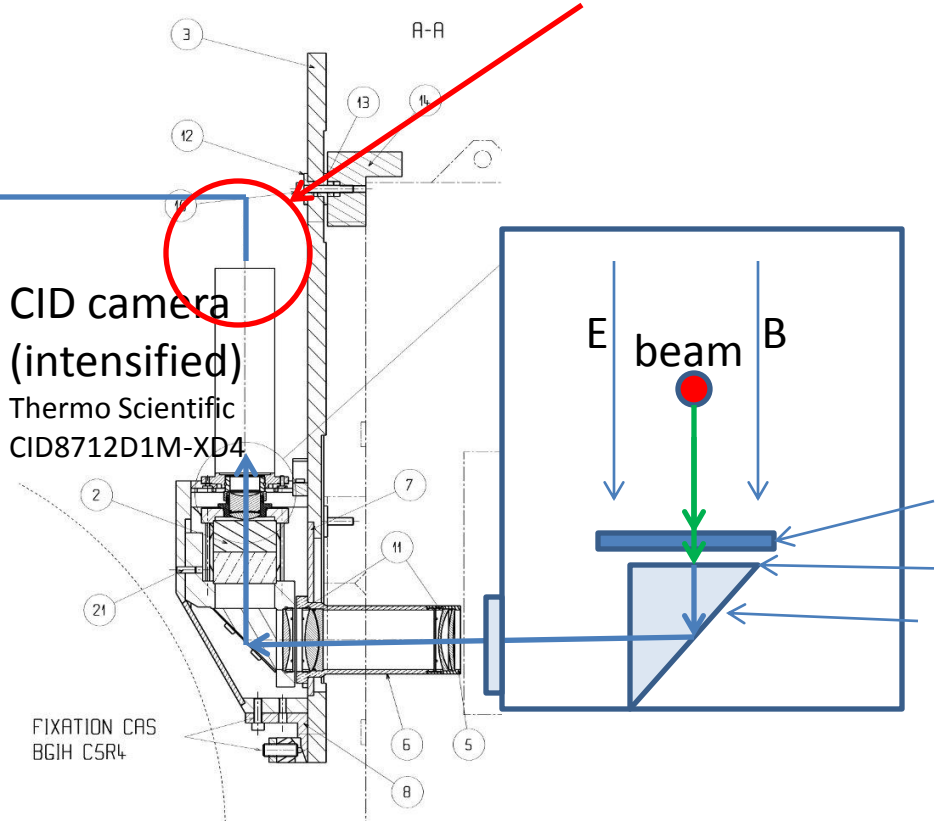
# Signal distortion

Frame grabber

~180 m

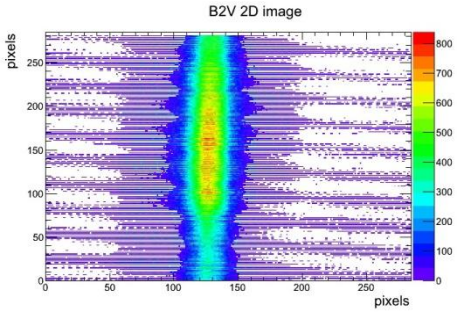
Video amplifier

Transmission using analog video signal:
- line-to-line noise and other artefacts









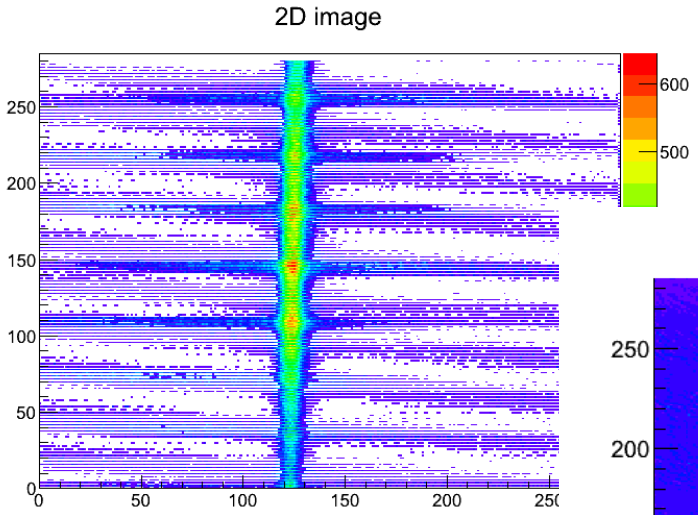
# Signal distortion

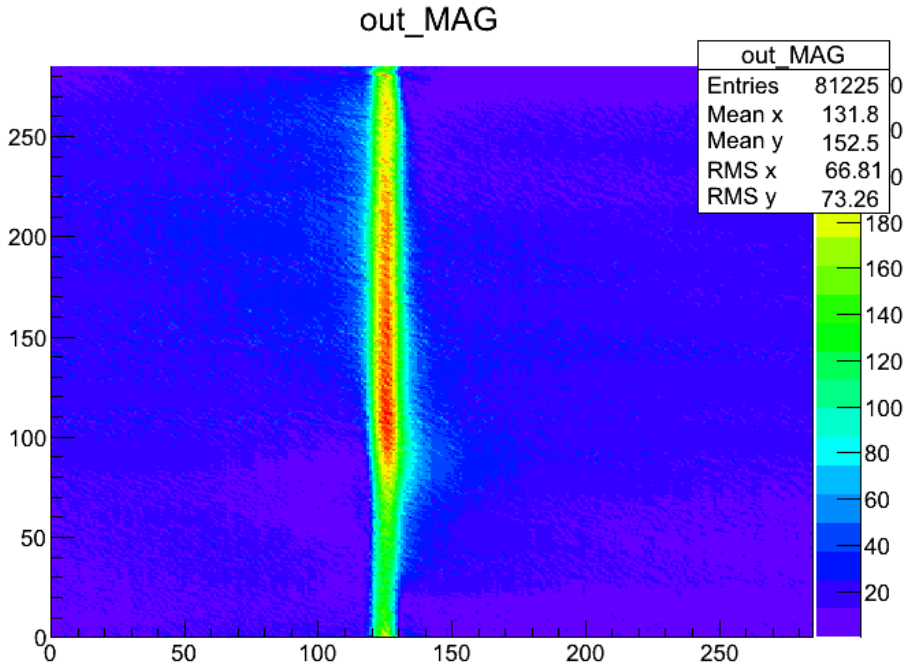
Frame grabbe

~180 m

Video a

Solution: image filtering, eg. 2D FFT filters (still being tested)



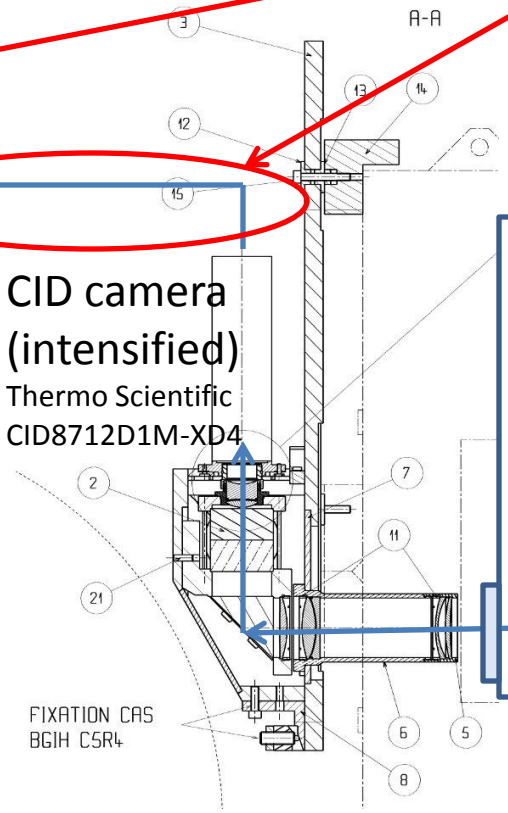



# Signal distortion

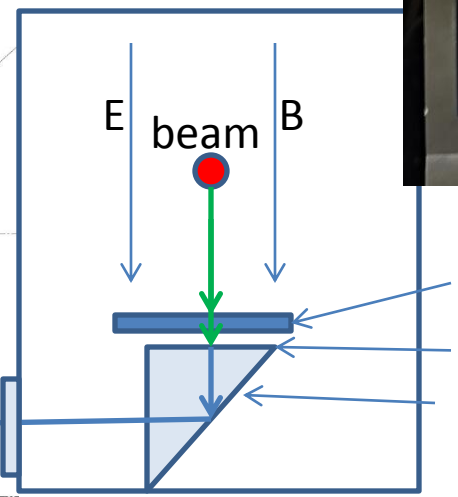
Frame grabber

SPS: picking up a huge noise on video signal correlated with beam type/intensity

~180 m




CID camera (intensified)
Thermo Scientific
CID8712D1M-XD4


MCP
Phosphor
Prism

Video amplifier

Optical system

View port

Cable shielding and exchange of video signal amplifier were helpful.

# Hardware failures (other than already mentioned)

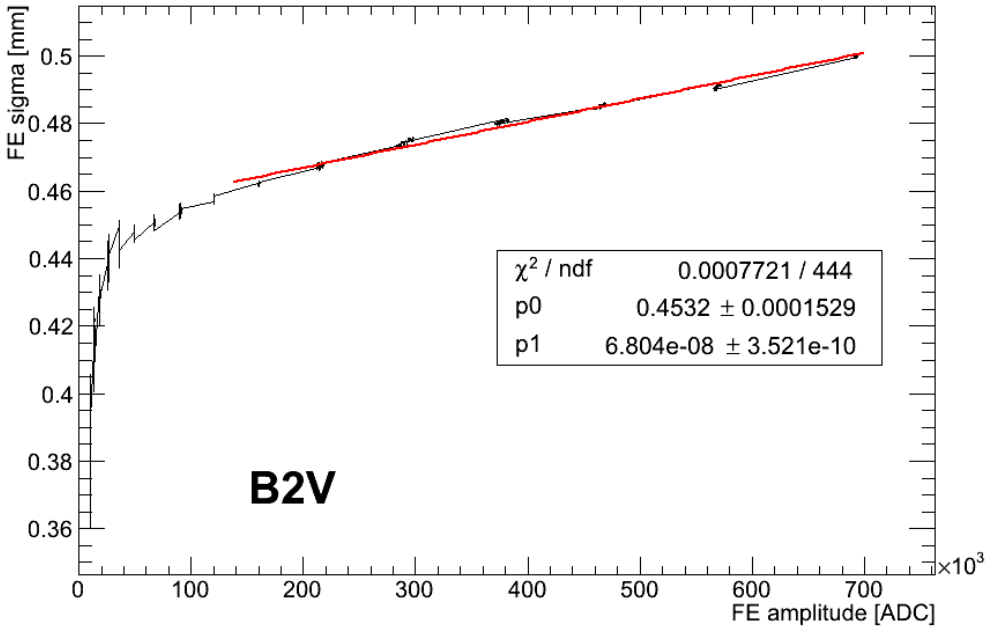
- HV ctrl card – problem with compatibility with VME (linux CPU)
- 5 CID cameras stopped working, in most cases we suspect that intensifier reached MTTF (tbc by ThermoFischer).
- failures of MCPs
  - "conditioning effect" for MCPs
  - too high input electron current might kill MCP
  - abrupt HV change might kill MCP (and dump the beam!)

Killed MCP: creation a conducting channel through the plate: cannot set HV anymore, cannot amplify the signal.

# Fit and amplitude dependence

- ROOT fitting library (the same as for BSRT)
- there is a dependence of measured beam sigma on the signal amplitude
- amplitude feedback is crucial (we do it through camera intensifier gain)

  (changing HV on the MCP in the vacuum is risky)

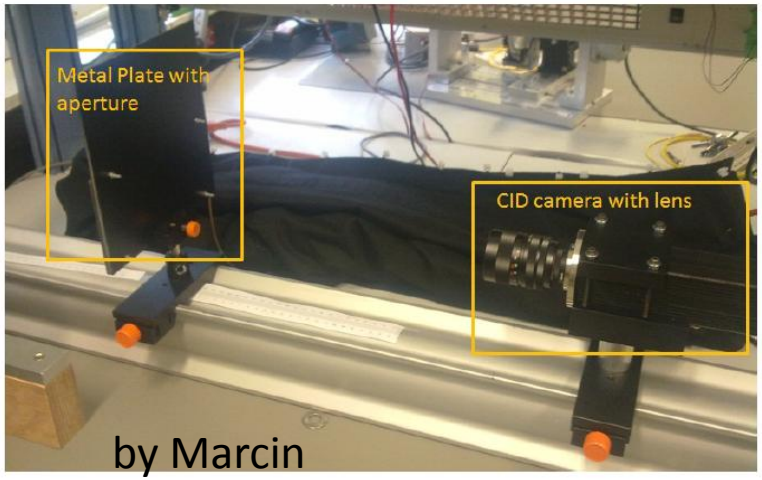


# Calibration from specifications

- Camera pixel size:  11.5 µm * 1.6 (taper)
- Optical system magnification: 0.2

Calibration = 92 µm/pixel

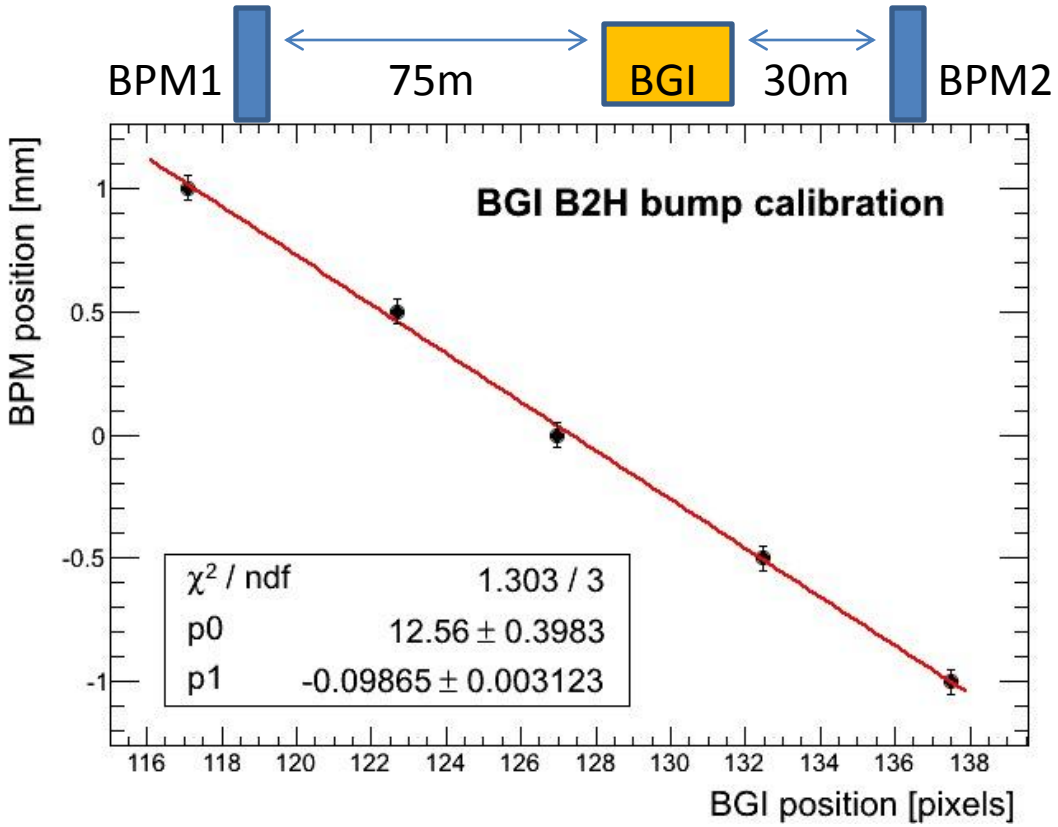
# Calibration in the lab




The value found:
115 ±3 µm/pixel

# Beam-based calibration

- Interpolate beam position from neighbor BPMs.
- Make an orbital bump
- Error on orbit position in BGI location: 100 µm (interpolation error)

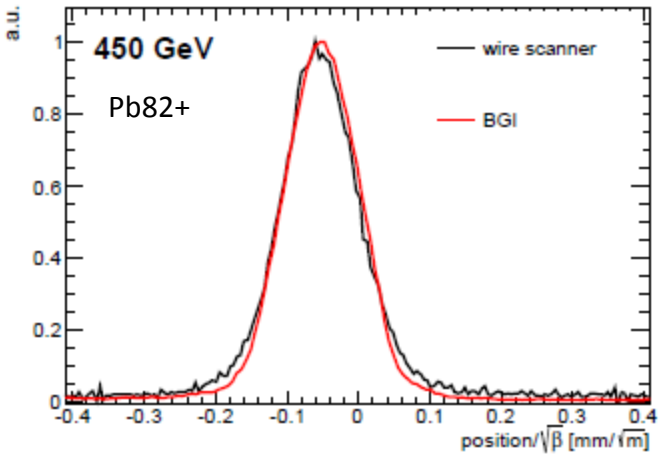


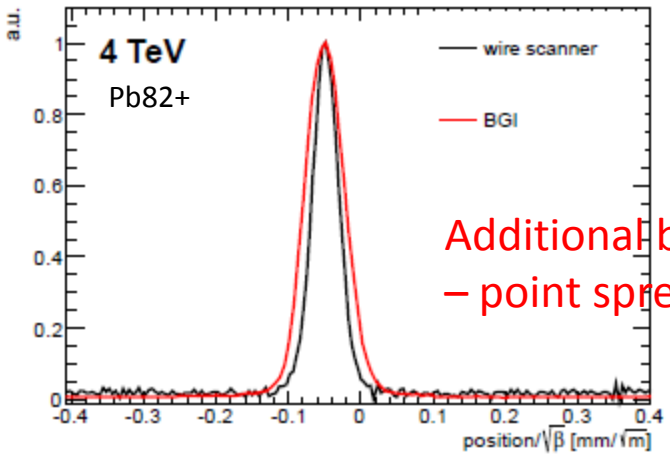

Calibration = 95-99 µm/pixel

Installation of BPM close to BGI is foreseen during LS1

# Cross-calibration (WS, BSRT)

- Because of old MCPs BGI sensitivity starts where WS cannot measure
- But for ions there was an overlap
- BSRT uses cross-calibration with WS, so calibration with BSRT is of "second order".



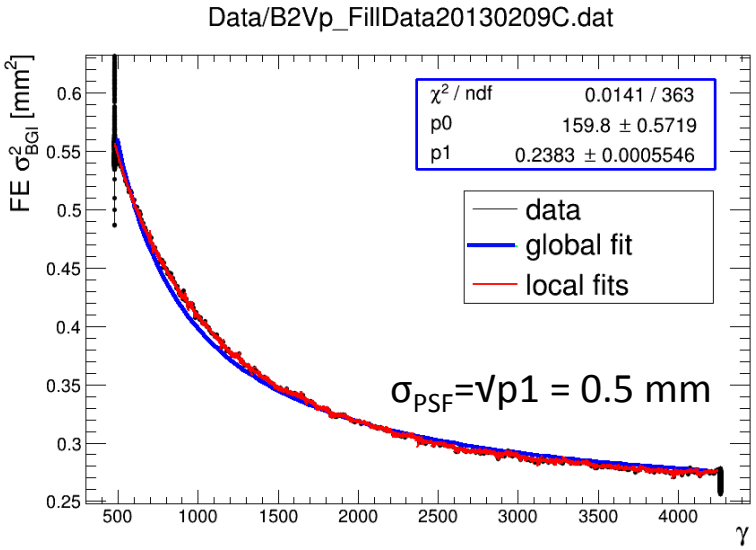



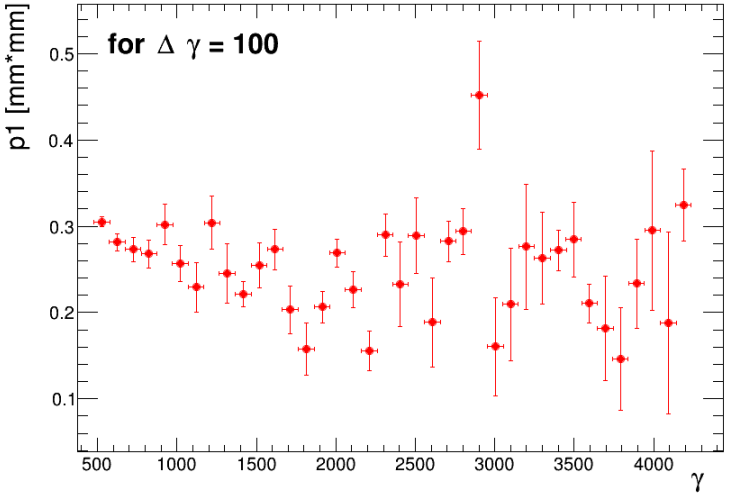

Additional broadening in BGI – point spread function?

| B2V [m] | WS | BGI |
|---|---|---|
| injection | 418.95 | 217.19 |
| flat top | 451.04 | 225.35 |

# Ramp-based calibration

$$\sigma^2_{meas} = \frac{\varepsilon\beta(\gamma)}{\gamma} - \sigma_{PSF}^{\ 2} + \ldots$$




It is possible to optimize the fitting procedure, but is the quadratic correction enough to correct for all errors, especially the beam space charge?


# Conclusions

1. LHC IPM deals with beams of unprecedented brightness.
2. System was  in commissioning for the whole period. Almost not used for operation during Run 1 because of difficulties to calibrate it.
3. But a lot of studies were done, a lot of data collected, significant upgrades.
4. We suspect that there are strong physical reasons behind calibration issue.
5. We think that we need a stronger magnetic field.
6. SPS IPM was renovated but noise on video signal was too large for most beams to use it.
7. There are some hints on how to reduce it.
8. A series of upgrades during LS1 is planned but we are happy to hear your advices.