
CERN

Photon detection system(s) - photon production and beam cooling observation functions

T. Lefevre on behalf on the BI group

Outline

- Diagnostic functionalities for GF-PoP
  - Measuring beam overlap
  - Measuring X-ray photon beam properties
  - Measuring beam cooling

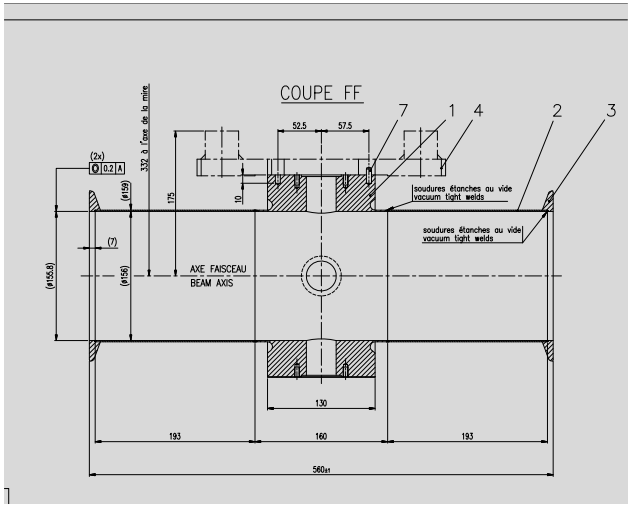
Diagnostics for GF-OP

- Beam position monitors around the laser cavity
  - Button beam-position monitors (BPMW) are installed on either side of the laser cavity
  - Using DOROS acquisition system which provides orbit data (integration over 1ms) with micron resolution (used on SPS on crab cavity system)
  - Using Alps electronics if turn-by-turn data are necessary (resolution worse for single bunch operation)

Diagnostics for GF-OP

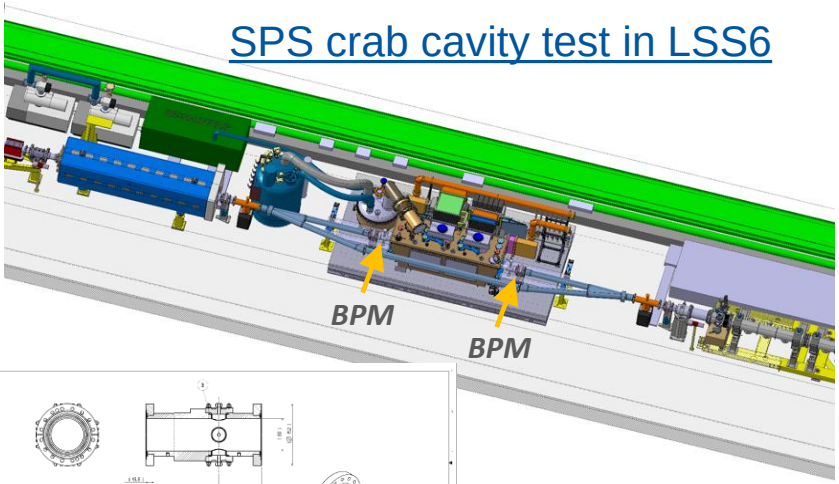
- Beam position monitors around the laser cavity : What exists on SPS ?

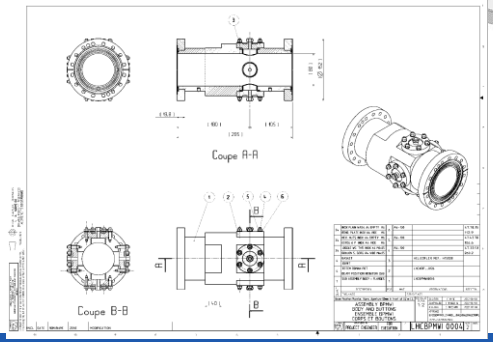
SPS button pick-ups (3 BPMs in LSS5)



Large aperture 160mm vacuum chamber LEP buttons (spare ?, old design)

SPS crab cavity test in LSS6

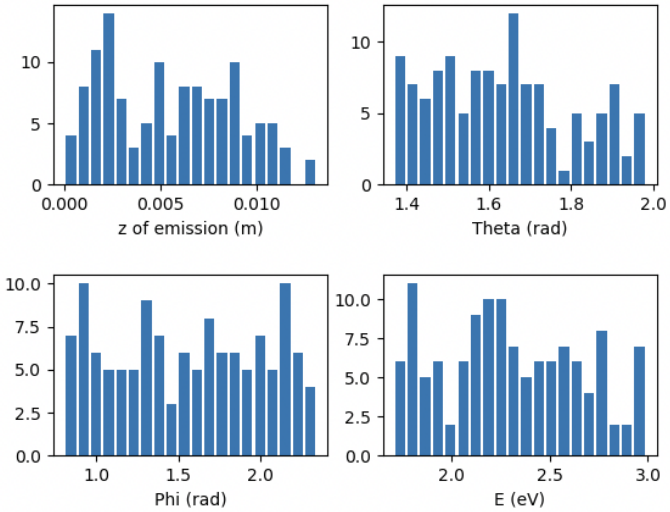




80mm aperture button (LHC design)

Diagnostics for GF-OP

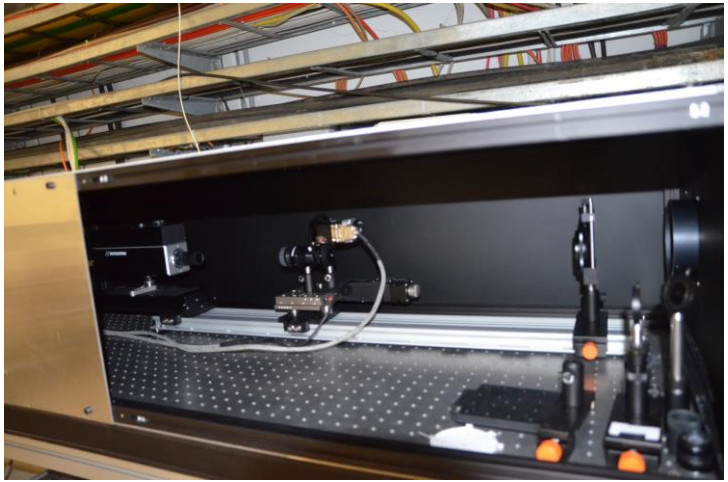
- Beam imaging system using emitted photon in visible range
  - From simulations performed by Alexey and Camilla showed few photons (<10) emitted per bunch crossing, in the visible range above the the IP (4x4cm area at 1cm above IP)



- Need highly intensified camera
- Need to integrate over many turns
- Issue with Background light ?

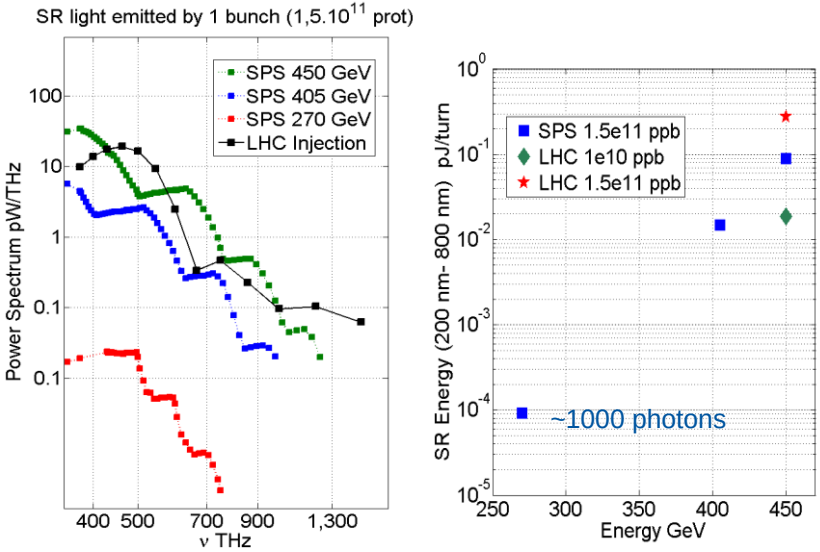
Diagnostics for GF-OP

- Beam imaging system using emitted photon in visible range
  - Experience with SPS synchrotron light monitor



Diagnostics for GF-OP

- Beam imaging system using emitted photon in visible range
  - Experience with SPS synchrotron light monitor (data from 2017)



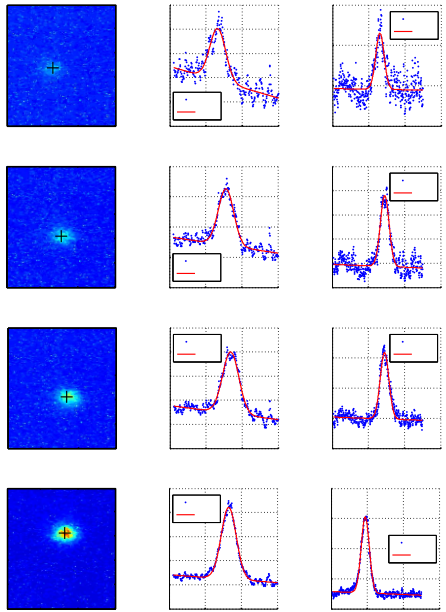
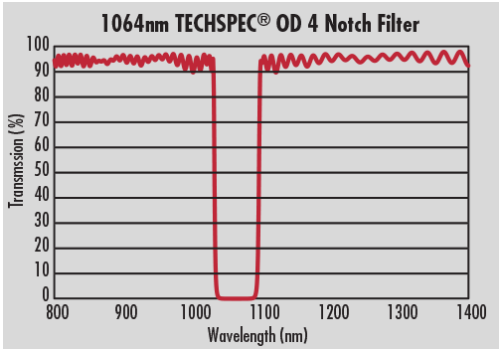


Figure 5.1: Imaged SPS SR light for a bunch of $\sim 10^{11}$ protons over 4 SPS turns along the energy ramp.

  - New Gig E camera/intensifier in 2018 (better S/N ratio)

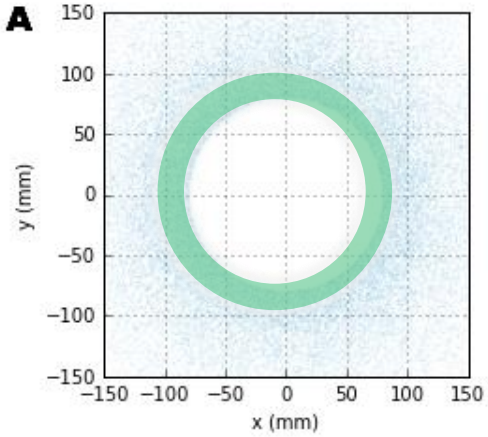
Diagnostics for GF-OP

- Beam imaging system using emitted photon in visible range
  - SR background for ions expected to be negligible in the visible range – still to be quantified !
  - Need to refine the number of collected photons using typical lens diameter of 80mm
  - Would we get more photons in the UV and at smaller angles (detection can be done from at angles smaller than 90 degrees – down to 60-70degrees ?)
  - Background will also come from the laser photons – this limitation should be removed using laser notch filter



X-ray photon Diagnostics for GF-OP

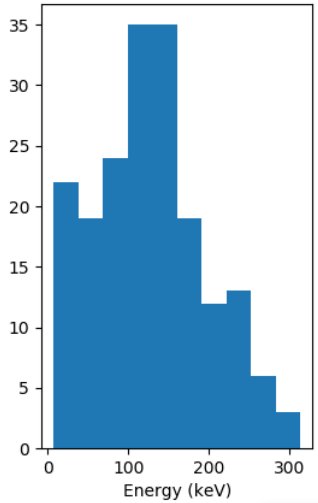
- From simulations performed by Alexey and Camilla
- Assuming a ring shaped detector (transverse size 1cm) located around the beam (d=80mm)



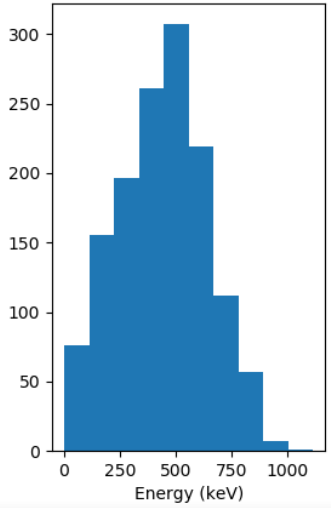
X-ray photon Diagnostics for GF-OP

- From simulations performed by Alexey and Camilla (per bunch crossing)
- Assuming a ring shaped detector (transverse size 1cm) located around the beam (d=80mm)

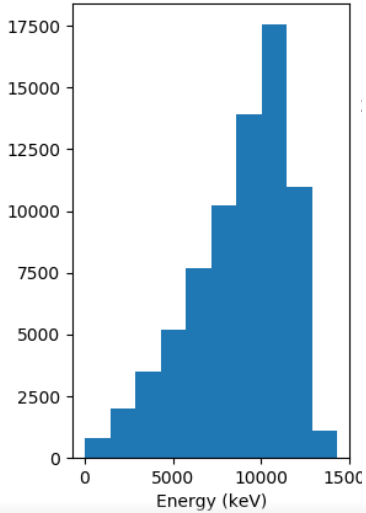
d=0.5m



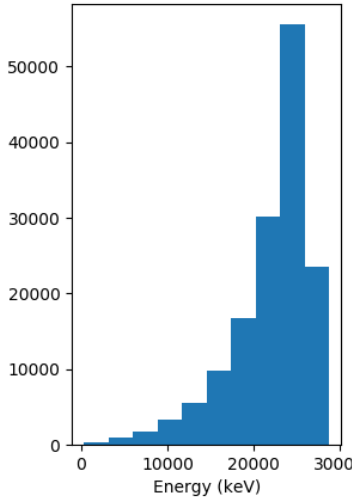
d=1m



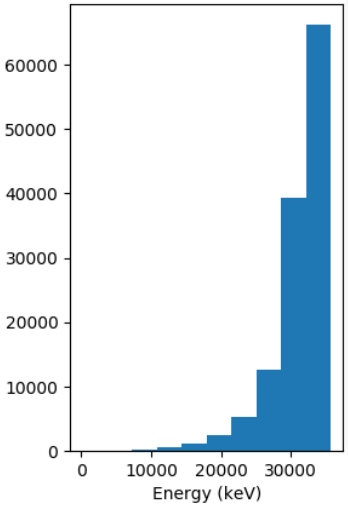
d=5m



d=10m



d=15m



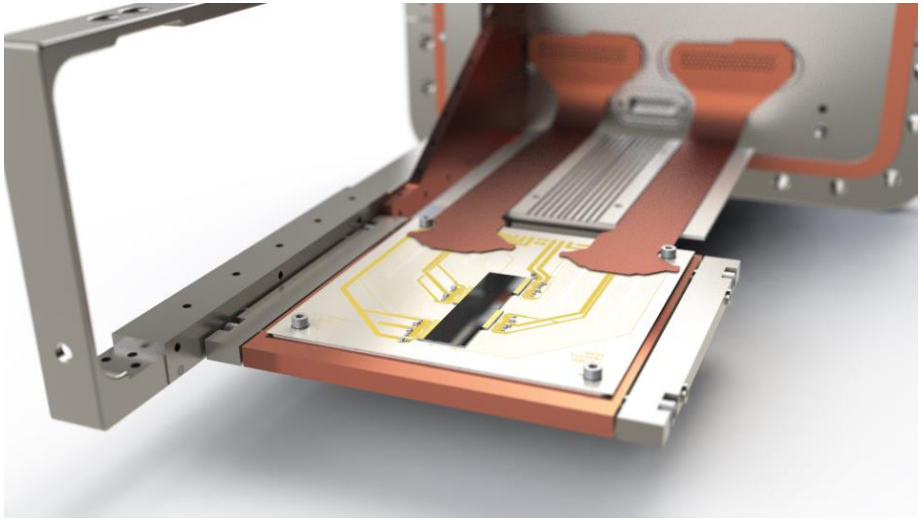
Large flux of photons in > 10keV range after 10m

X-ray photon Diagnostics for GF-OP

- Example on SPS using Pixel detector – Timepix3

https://medipix.web.cern.ch/technology-chip/timepix3-chip

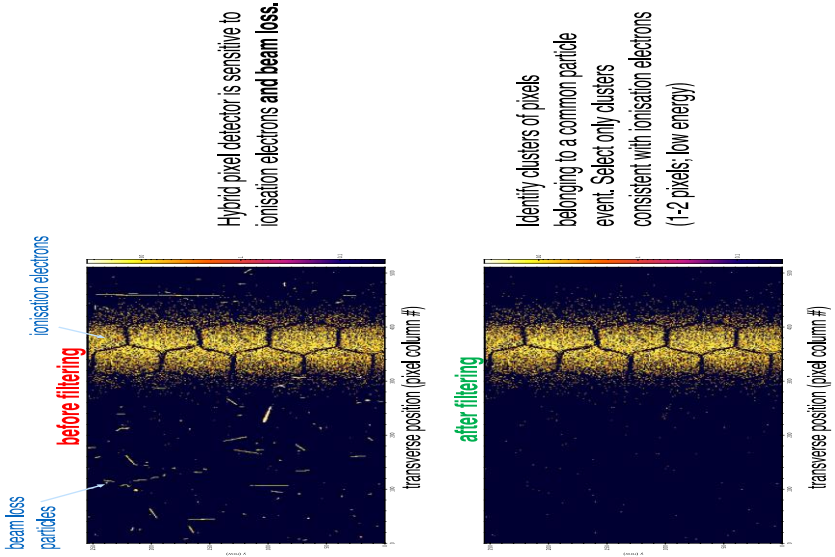
http://bgi-web.web.cern.ch/bgi-web/

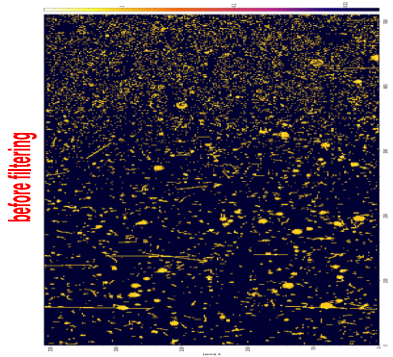


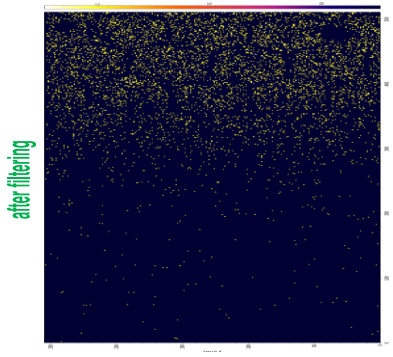
- CMOS : 256x256 pixels (55umx55um)
- Rad-hard read-out electronic system
- Operational on PS since 2017

X-ray photon Diagnostics for GF-OP

- Example on SPS using Pixel detector – Timepix3

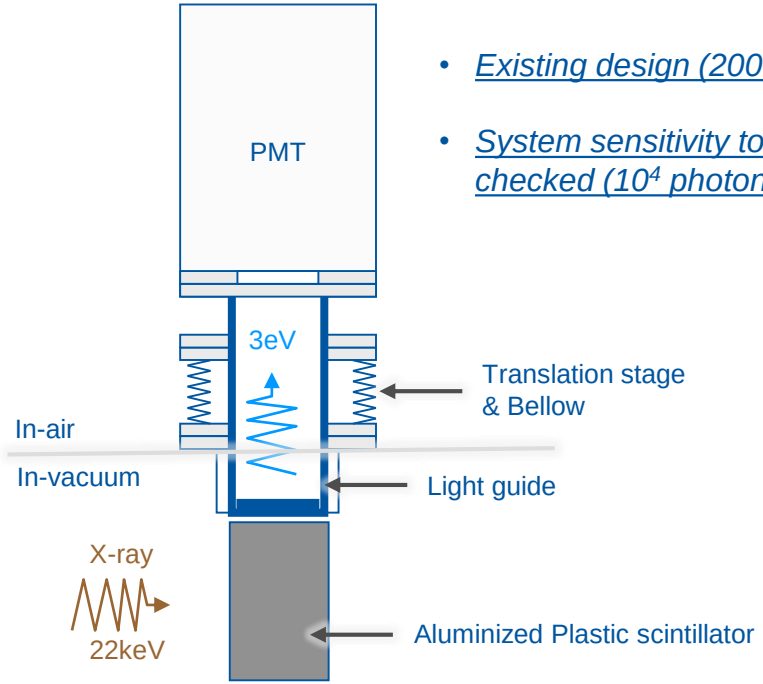




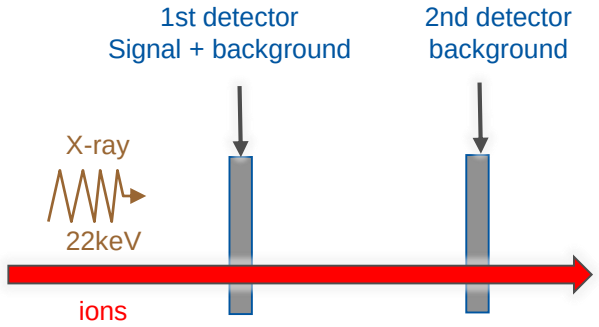


Beam diagnostics for GF-OP

- X-ray detection system using lead loaded plastic scintillator

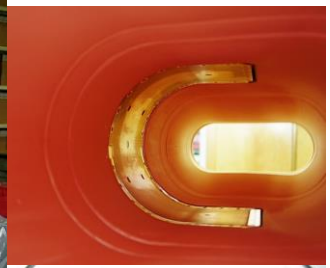


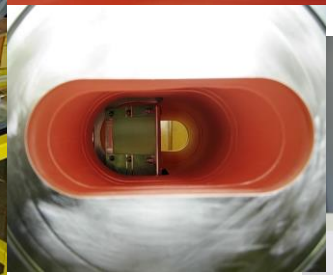
- *Existing design (2001)*
- *System sensitivity to be checked (10^4 photons/pulse)*

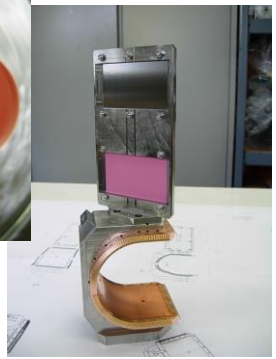


X-ray photon Diagnostics for GF-OP

- Example of devices with replacement chamber

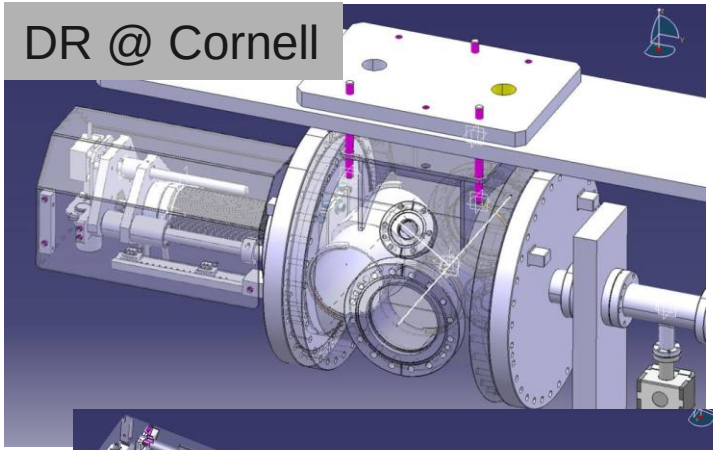


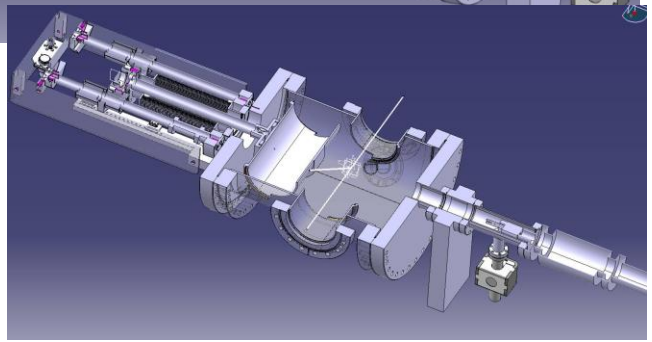




BTVSE@LHC

DR @ Cornell

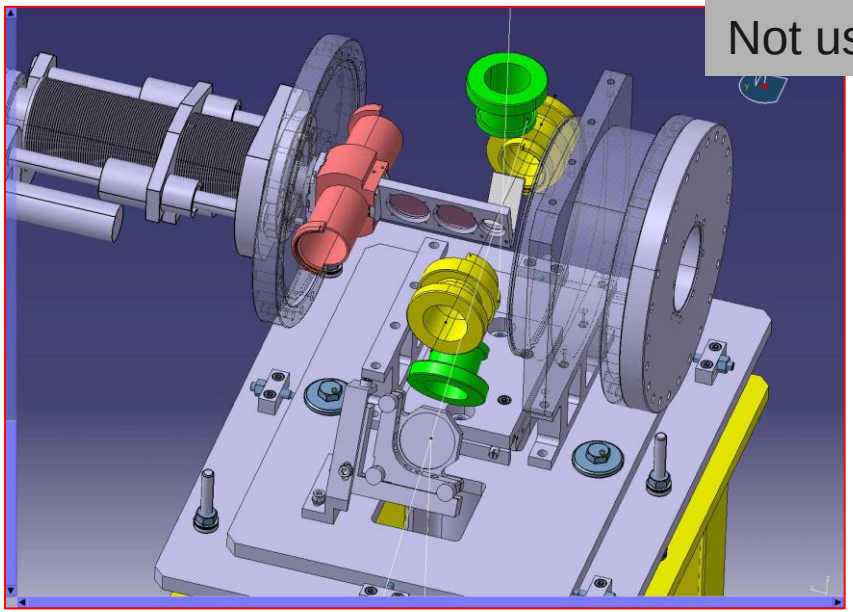


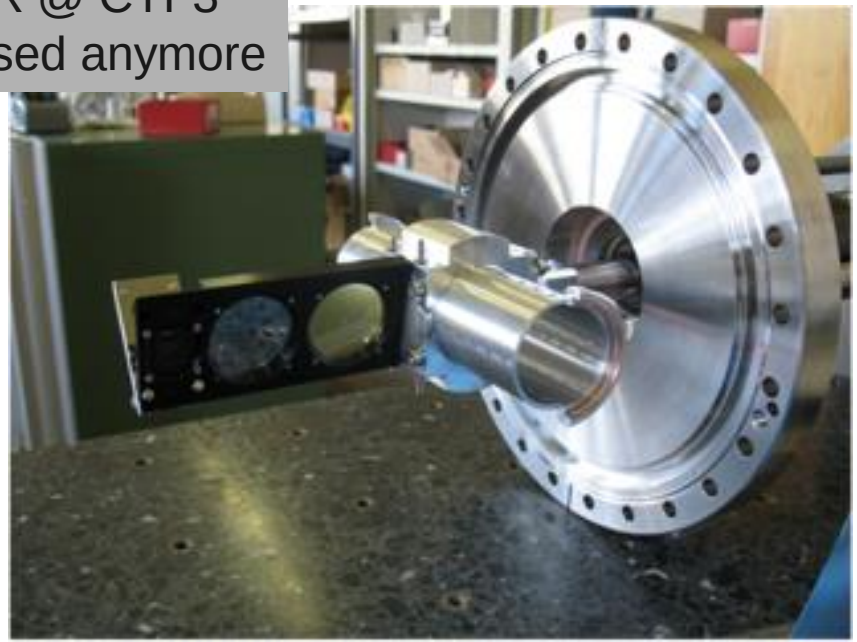


X-ray photon Diagnostics for GF-OP

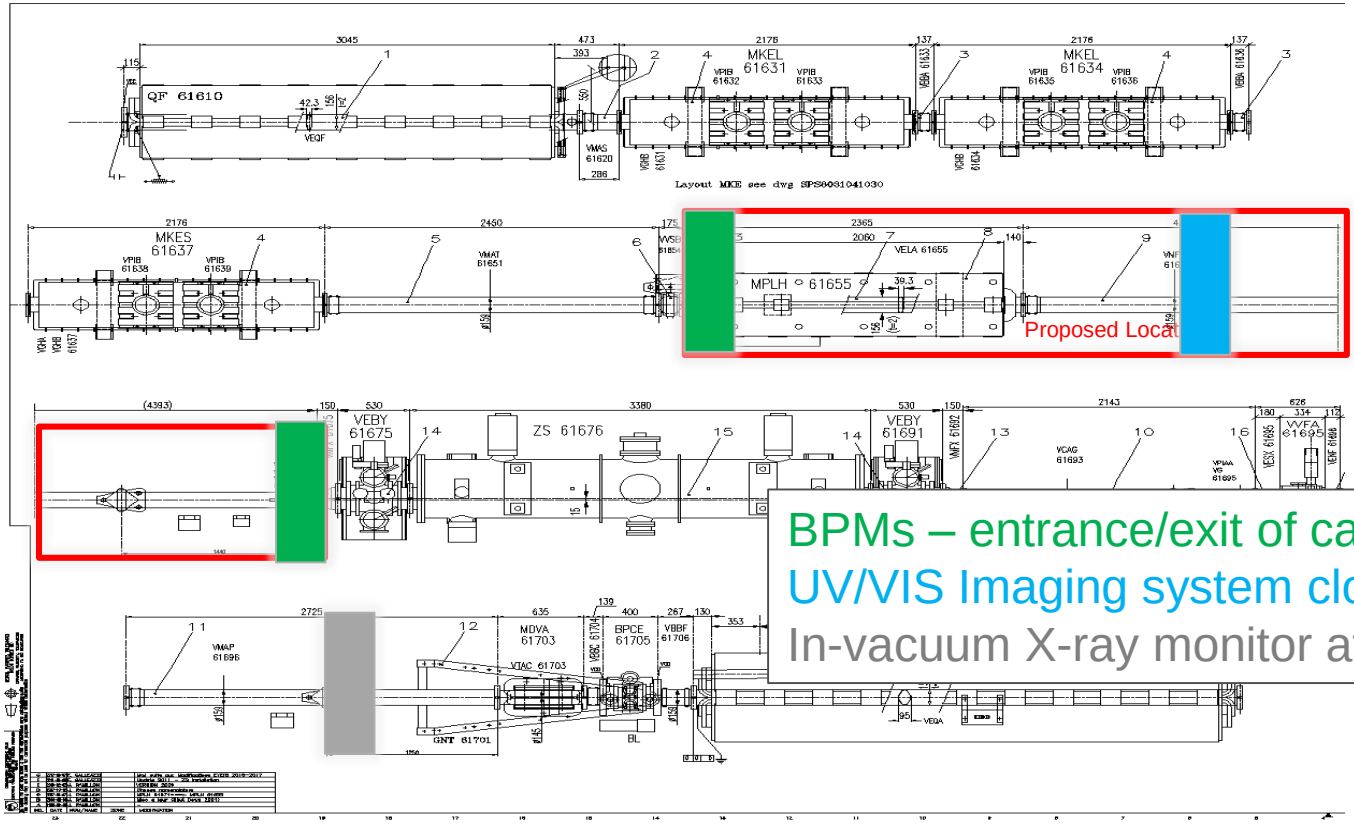
- Example of devices with replacement chamber

OTR @ CTF3
Not used anymore





Beam diagnostics for GF-OP



BPMs – entrance/exit of cavity

UV/VIS Imaging system close to interaction point

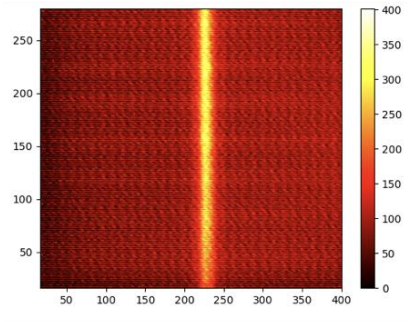
In-vacuum X-ray monitor at 10m from IP

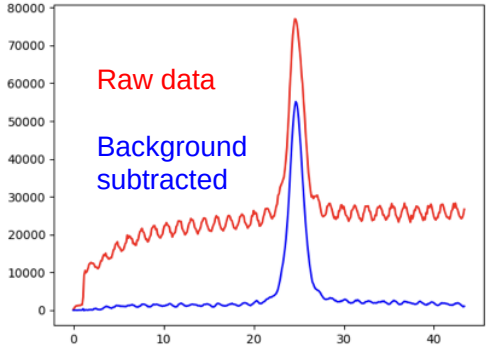
Beam diagnostics for GF-OP

- Measuring longitudinal beam cooling
  - Several monitors available in SPS with sub-ns resolution (BQM, WCT or HT-monitor)
    - Bandwidth up to 3GHz
  - Bunch-by-bunch, turn-by-turn longitudinal beam profile possible
  - Need to check if the current read-out system is adequate for our need - how many measurements per second are needed ?

Beam diagnostics for GF-OP

- Measuring transverse beam size
  - Not enough SR for ions for BSRT
  - Wire scanner – risk of stripping ?
  - Beam gas ionization profile monitor





  - Very clean profile after background subtraction
  - Smallest intensity that can be detected in a single cycle = ~10e10 p
  - Open questions and future investigations
    - Do we need gas injections ? Sensitivity with single ion bunches ?

Conclusion

- Add BPMs in the laser cavity

- Challenging monitors
  - Need a replacement chamber for Photon X-ray monitor
  - Background issues to be investigated (with beam in 2021)
    - Visible light monitor system using SPS BSRT equipment
    - X-ray background outside of vacuum as a first step ?
  - Two (maybe more) possible technology choice for X-ray monitor
    - Going to more realistic detector study (simulations of realistic design size /shape, including background in BDsim?)

- Can we foresee X-ray detection outside the vacuum :
  - Thin window after first dipole ? How many photons do we expect there ?

Thank you