BEAMSSTRAHLUNG MONITORING

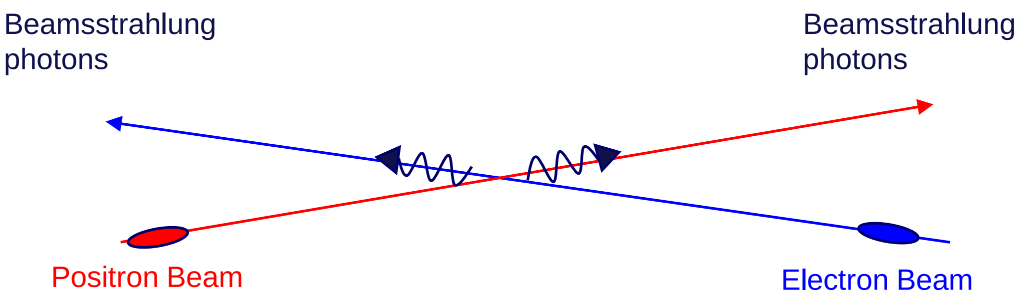
Robert Kieffer, on behalf of the MDI working group and of the CERN BI group.

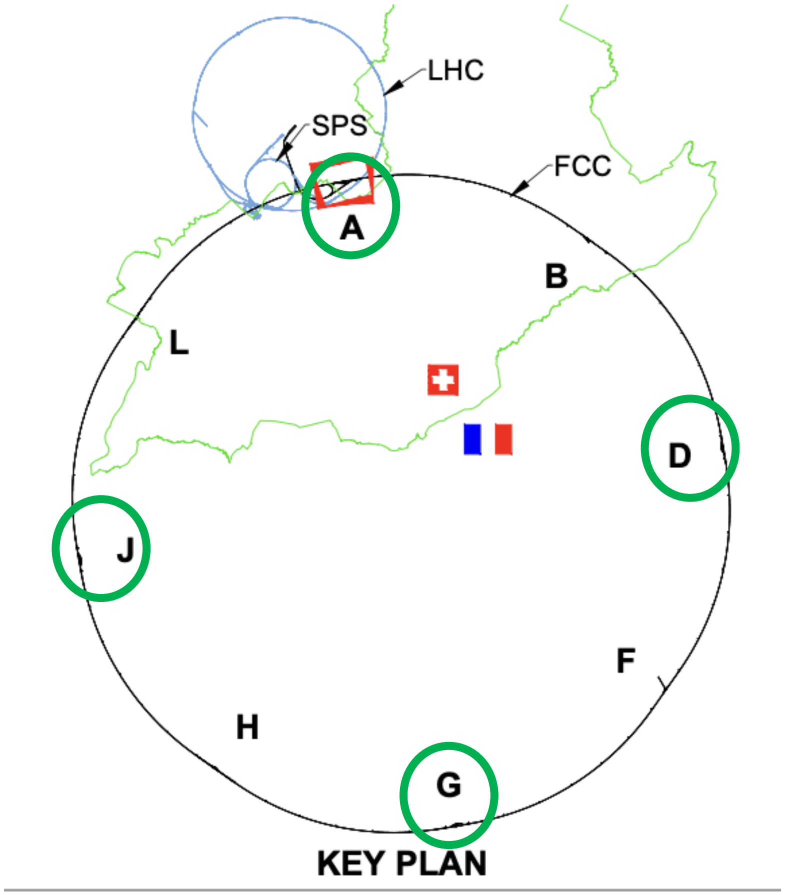
Luminosity Monitors

Each of the four experimental IPs will be equipped with a pair of Beamsstrahlung extraction lines and associated dump.

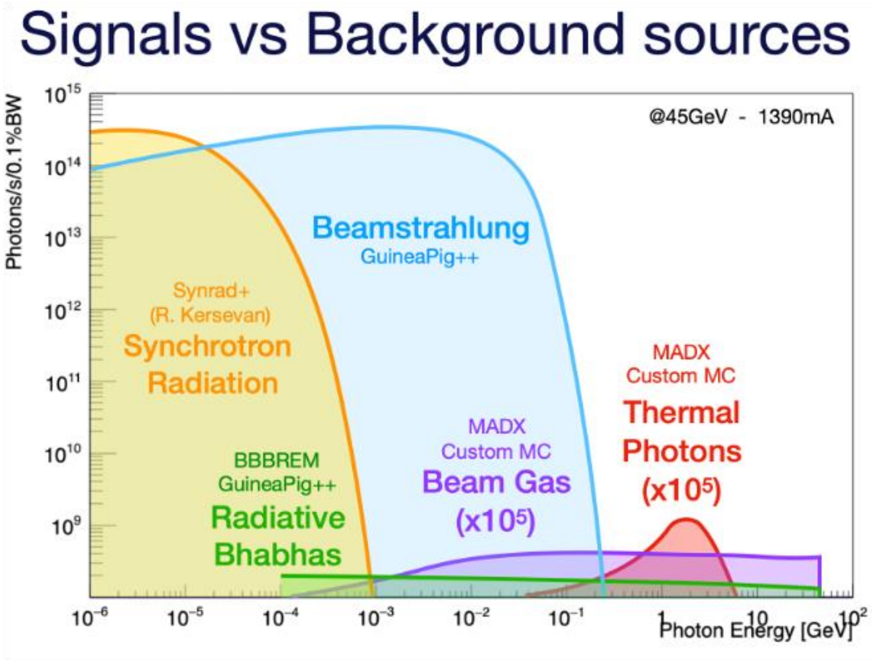
Each of these extraction lines will be equipped with the same instrumentation systems (8 lines total).

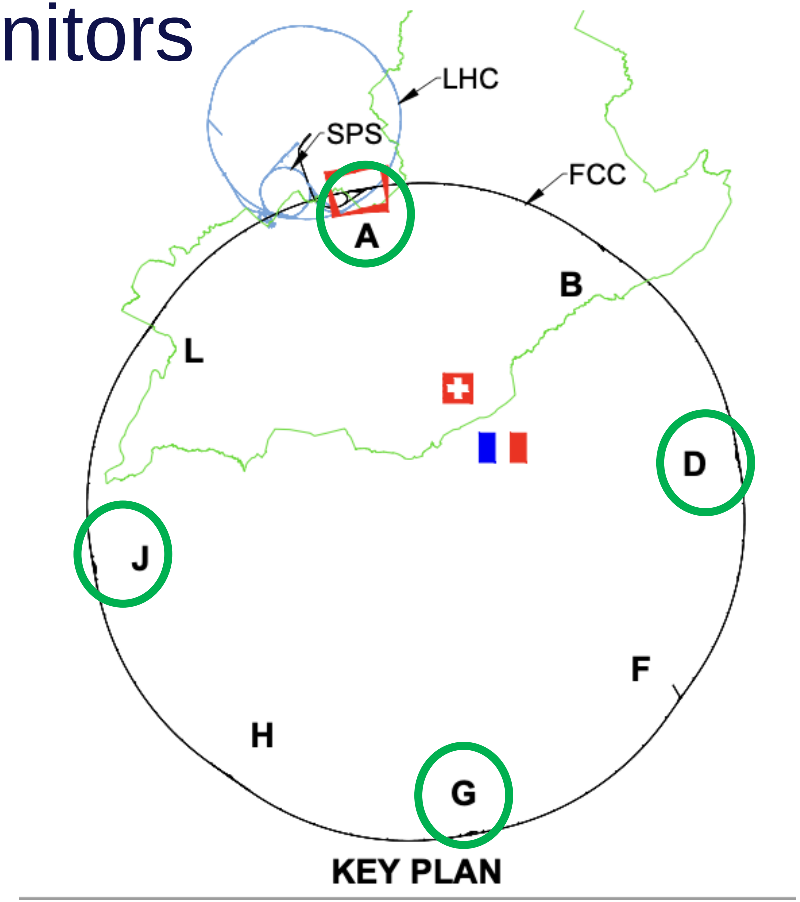
Monitoring of the Beamsstrahlung signal and the Bha-Bha scattering events will allow precise IP tuning for increased luminosity.





FCCee Beamsstrahlung Monitors



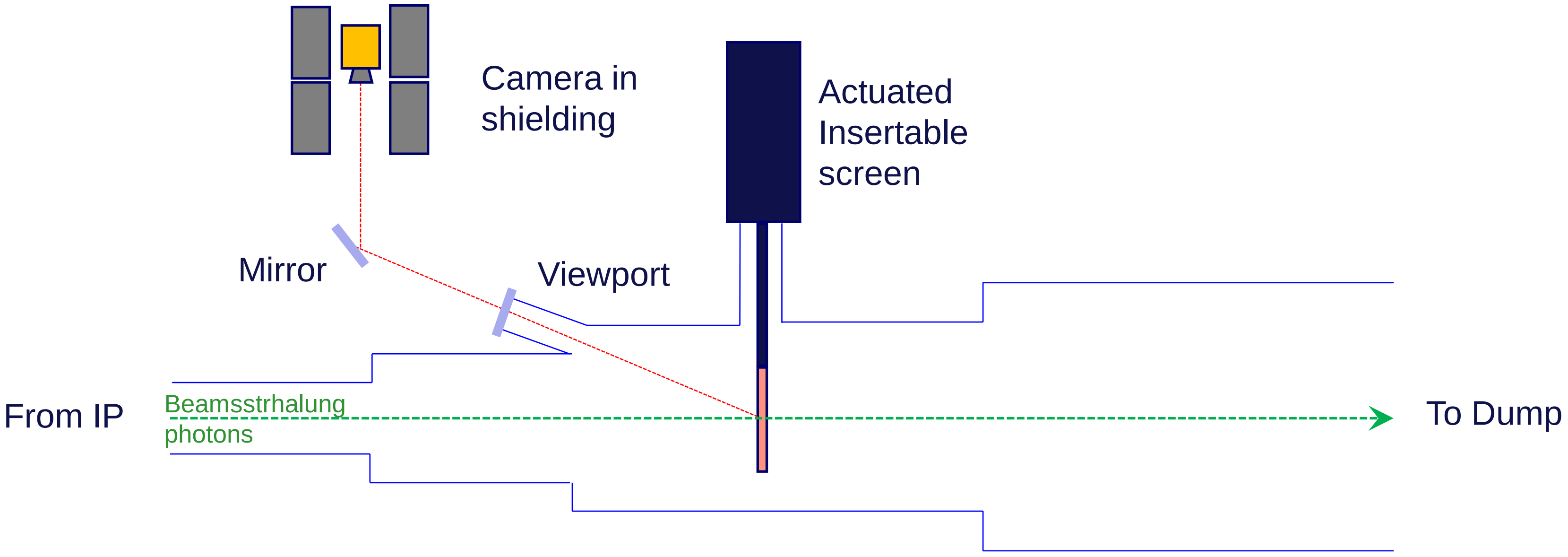


Why?

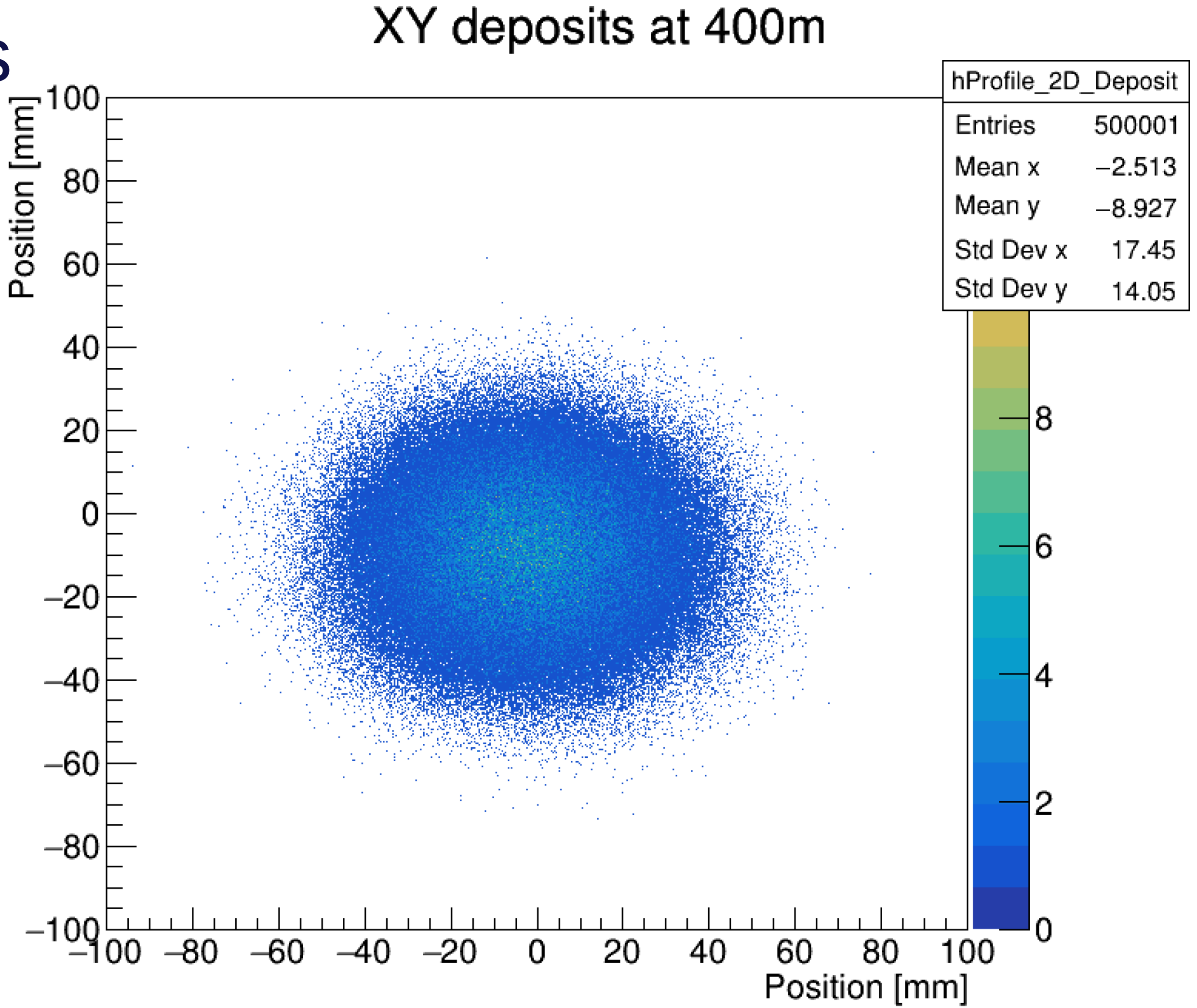
Need to track the Beamsstrhalung photons profile shape and position to feedback on IP tunning knobs.

Optical line to monitor a scintillating screen on the extraction line.

- Could be inserted at low intensity for IP tuning procedures
- Heat deposition study: Monte Carlo simulation of particle matter interaction.
- Cooling system for the screen?
- The study will define the accessible range of bunch-charge (Beamsstrahlung at the IP / heating the screen)
- Positioning: Be as far as possible from IP (dilution) and not to close from the dump (radiation background).



Expected Profiles

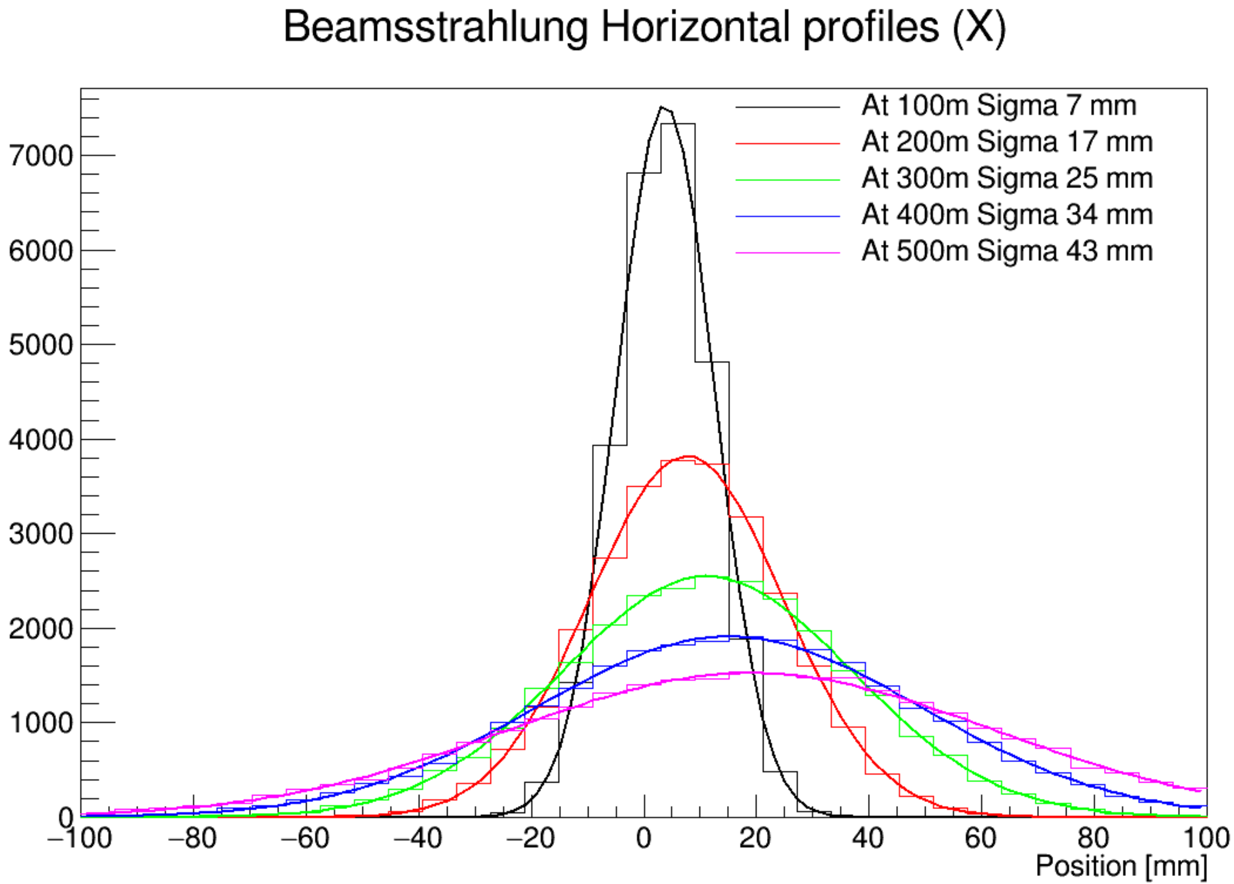


Offset at IP 250nm
500k photons events recorded
Spot size is around 15mm sigma

Expected Profiles

Power deposited :

Peak power reduced by a **factor 3** from 100m to 400m monitoring position.



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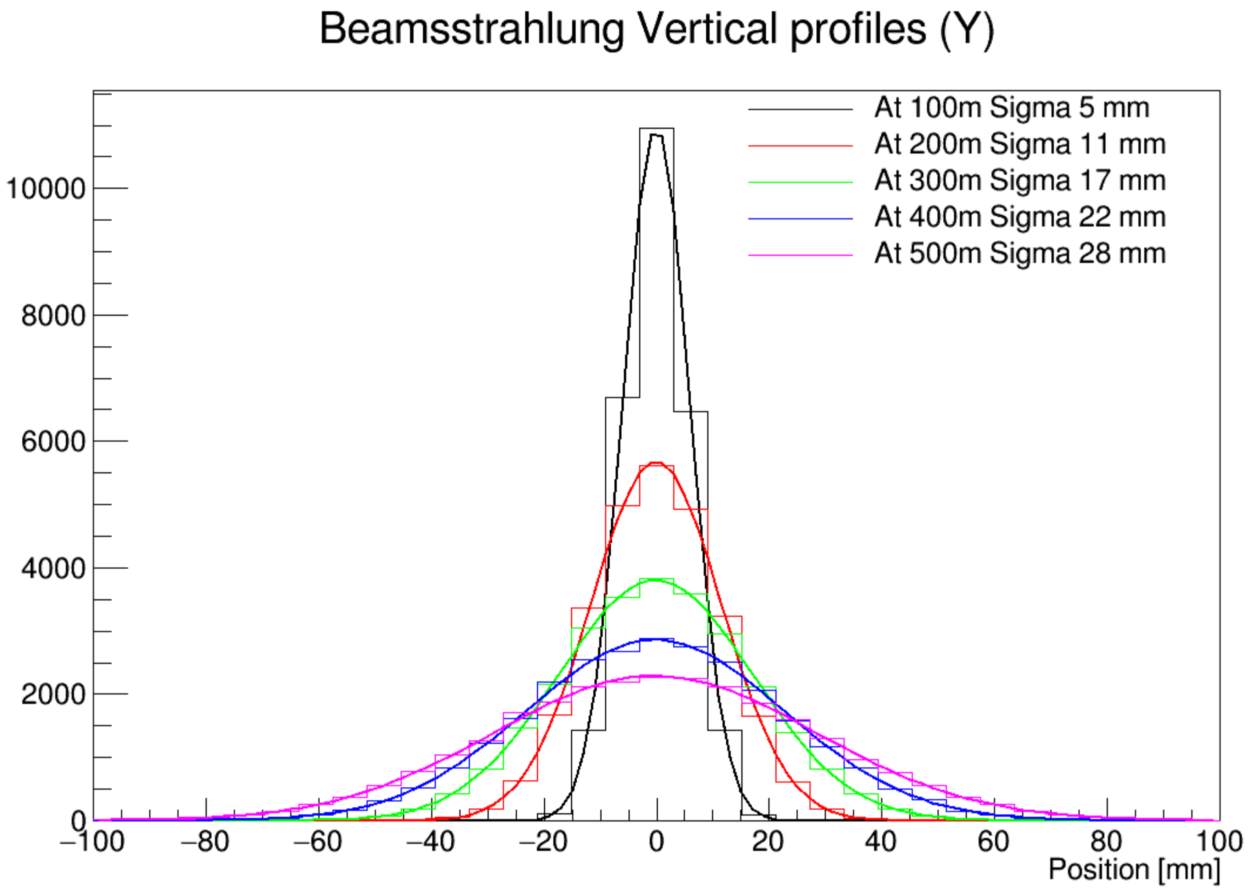


Comparison of scintillators screen materials

Study : Deposited power load by Beamsstrahlung and Thermal dissipation

Material	Rad.lenght (g.cm^{-2})	BS dep. In 1mm (Watt)
CVD diamond	42.7	548
Chromox Al2O3	27.94	935
YAG	14.82	2052
NaI	9.49	2677

CVD diamond is the best candidate due to low density and very high thermal conductivity !

- To be checked if the fluorescence is well optimised with the BS spectrum
- Might only be sensible in the optical range, and would be contaminated by SR

Used in most LHC's BTV the Chromox is the next obvious candidate

- Used in most beam dump lines to infer dump extraction/dilution profiles at CERN
- Can be brazed to the support to optimize thermal transfer

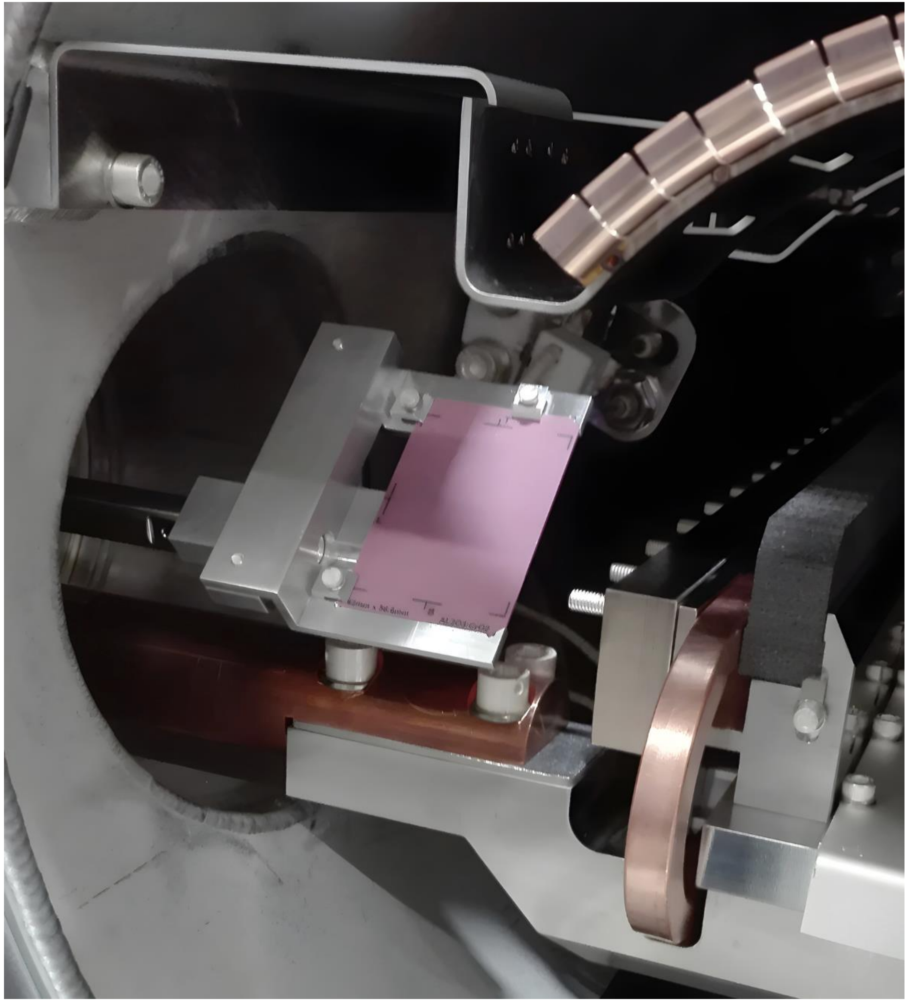
Chromox Screens

Scintillating inorganic material
Based on doped alumina.

Available in thicknesses from 150um to 1mm

Used in most beam dump lines to infer dump extraction/dilution profiles at CERN

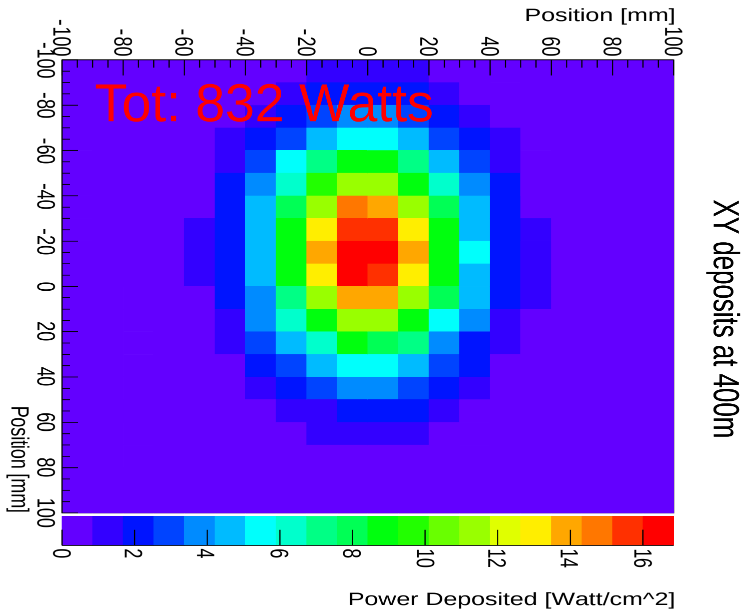
Most used for charged particle detection, also used in light sources to monitor Xrays.



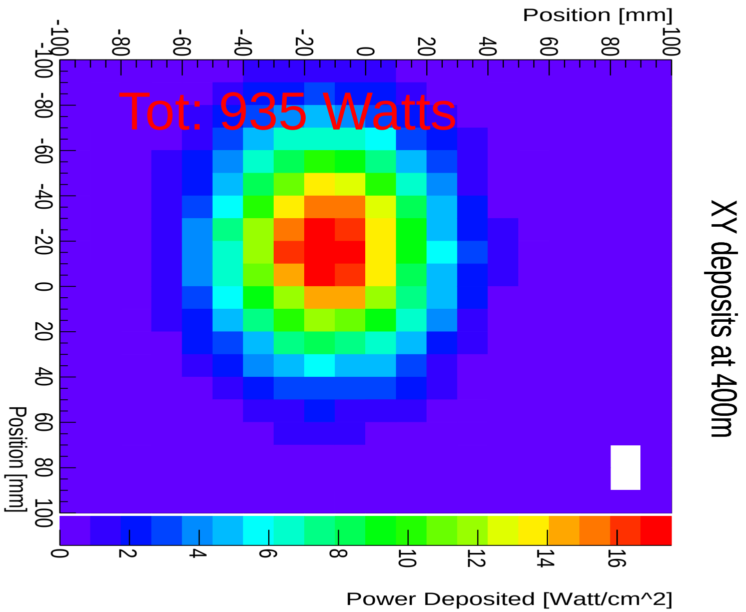
Beamsstrahlung pattern at Z mode scale
Energy deposition profiles in 1mm Chromox Screen

Source: BDSIM using Livermore physics list

Z mode, beam-beam Y offset 0nm
Expect 1100E15 photons / second



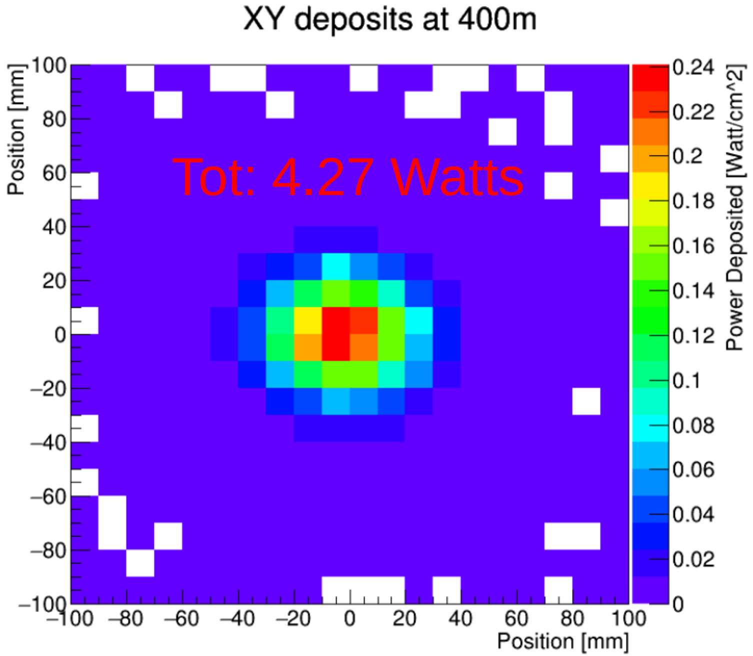
Z mode, beam-beam Y offset 250nm
Expect 1230E15 photons / second



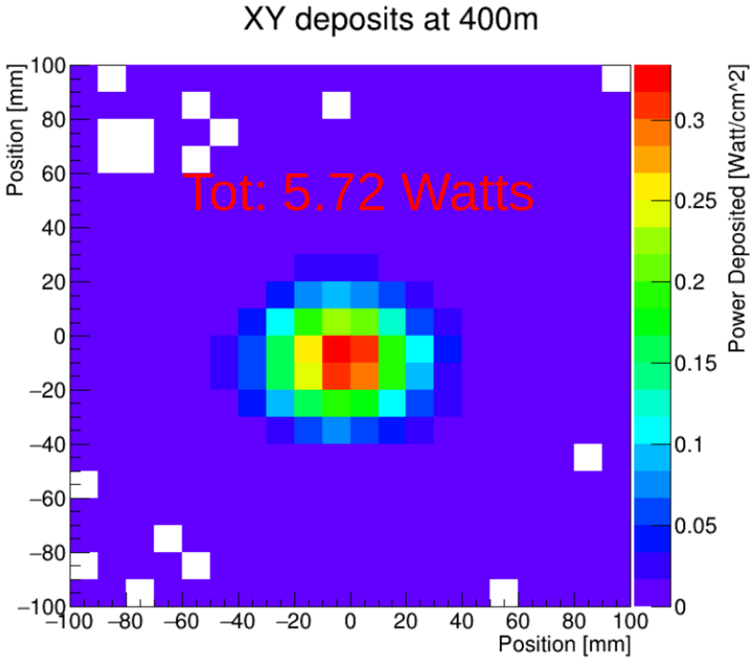
Beamsstrahlung pattern at ttbar mode energy scale
Energy deposition profiles in 1mm Chromox Screen

Source: BDSIM using Livermore physics list

ttbar mode, beam-beam Y offset 0nm
Expect 5.07E15 photons / second



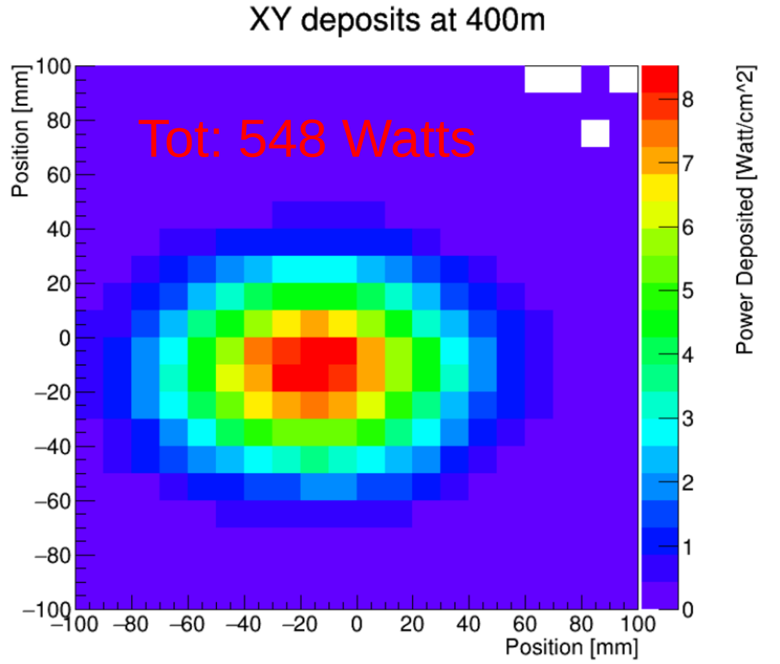
ttbar mode, beam-beam Y offset 250nm
Expect 6.75E15 photons / second



Beamsstrahlung pattern at Z mode scale
Energy deposition profiles in 1mm CVD diamond

Source: BDSIM using Livermore physics list

Z mode, beam-beam Y offset 250nm
Expect 1230E15 photons / second



In the worst case a screen of CVD diamond would get 548W it could be less if we could have screen thickness of few hundred microns.

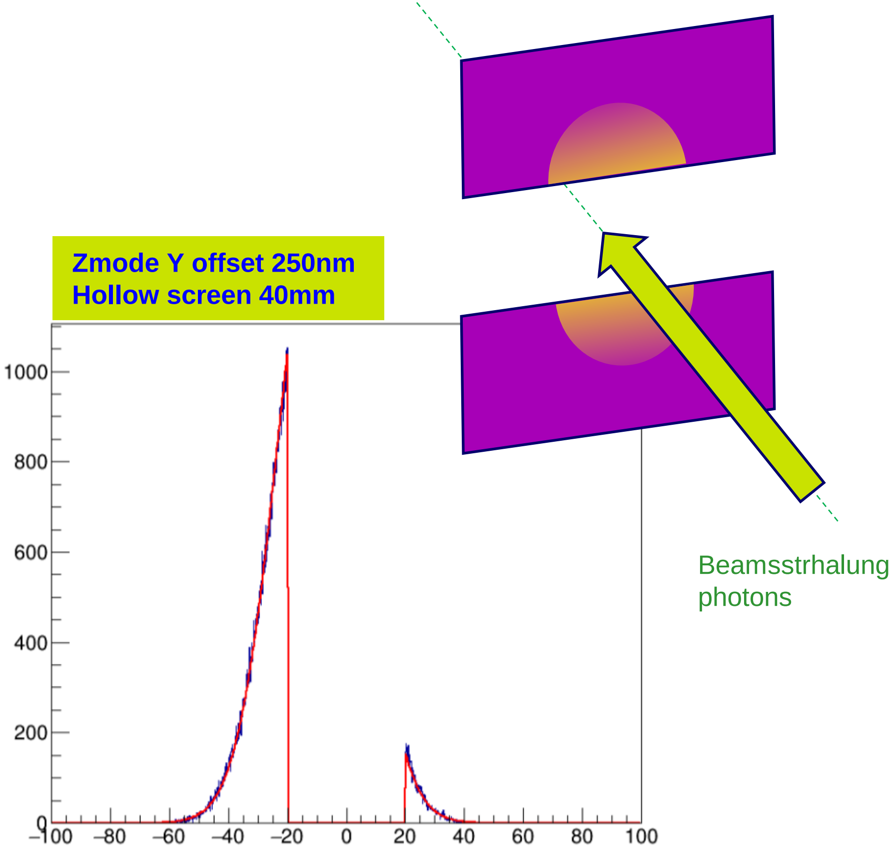
Maybe if the cooling is efficient we could use full screen.

Problem is the dimensions 20x20cm in CVD
The largest CVD diam. wafers on the market are: 4 inch

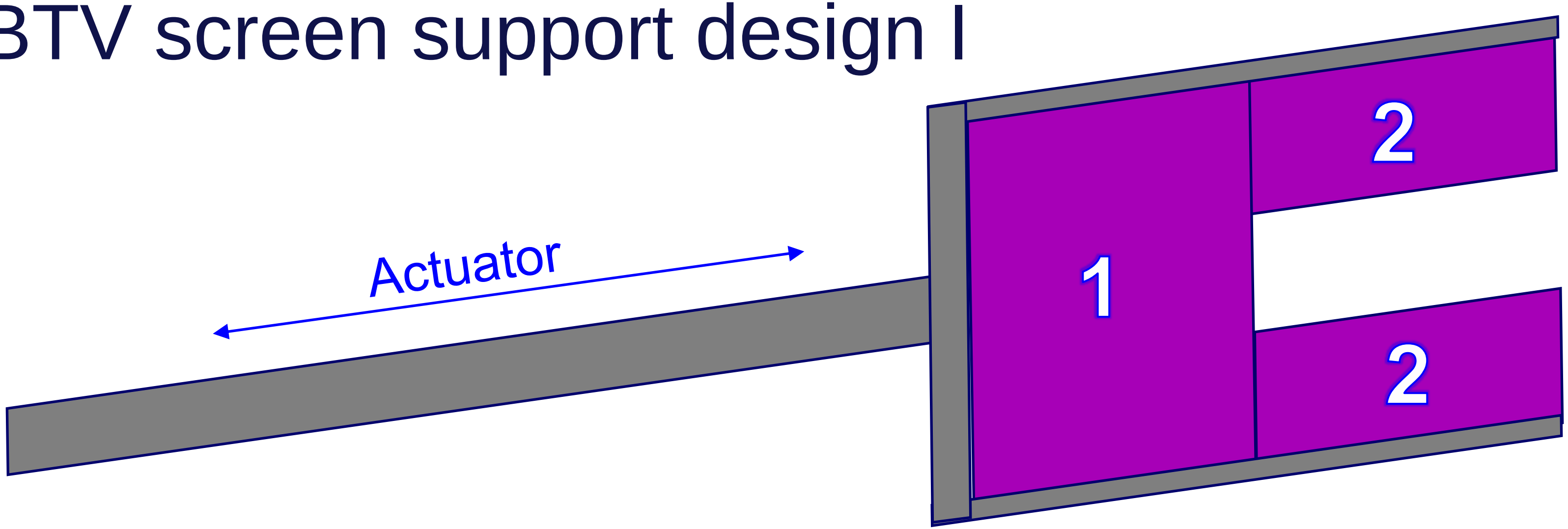
Catching tails with Screens

To overcome the heat load we could use partial screen coverage.

- Removing the core which is overheating
- Fitting the tails only to track the Beamsstrahlung profile position.
- Need to define the precision of the tracking depending on the aperture.



BTV screen support design I

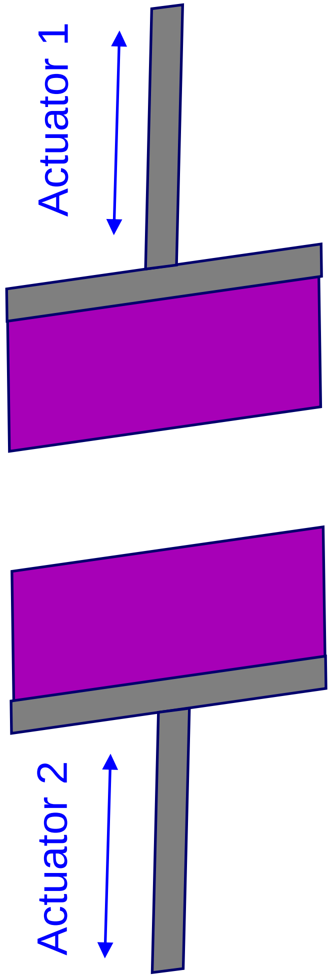


1. **Full screen** for machine commissioning at lower beam current. Ex: 12 colliding bunches instead of 11200. Full IP beam offset scan allowed.
2. **Partial screen** for full intensity beams monitoring at Z mode, limited range allowed ex: -50nm to 50nm

BTV screen support design II

Another possibility is to use a dual-jaw geometry

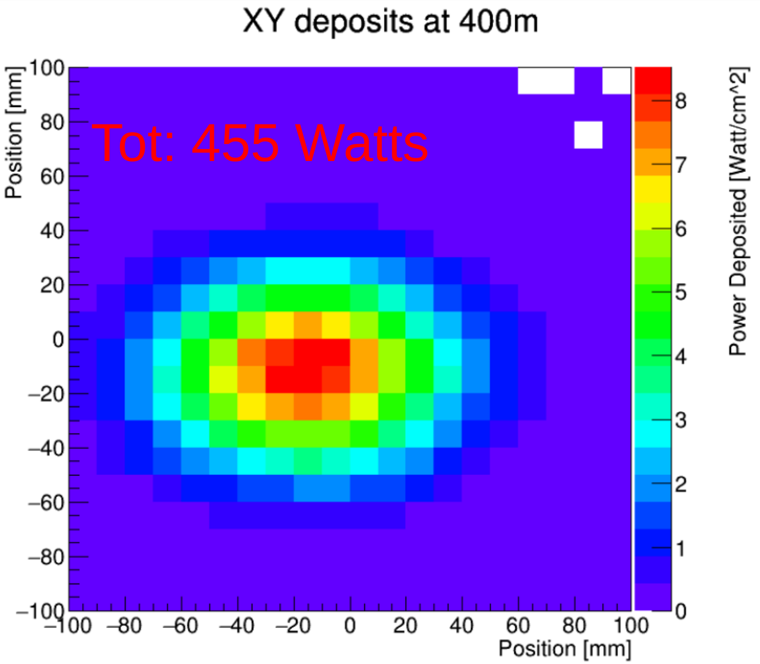
- Allow to remove the core which is overheating
- Fitting the tails only to track the Beamsstrahlung profile position.
- We can optimise the precision of the tracking depending on the aperture.
- The aperture will depend on the IP tuning scan range and beam charge.
- The device could be calibrated and used fully closed for commissioning with few bunches.



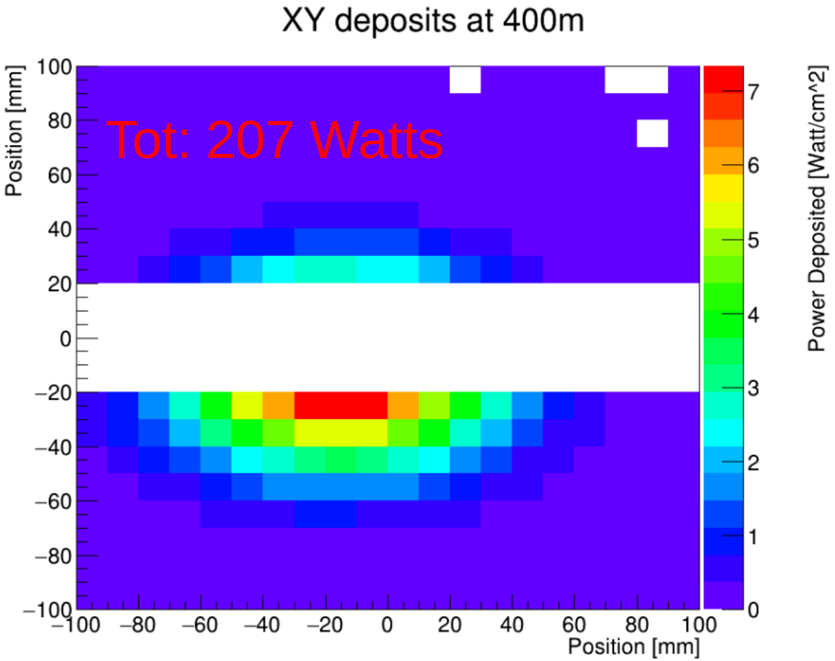
Beamsstrahlung pattern at Z mode scale
Compare power when using a hollow screen

Source: BDSIM using Livermore physics list

Z mode, beam-beam Y offset 250nm
Expect 1230E15 photons / second



Z mode, beam-beam Y offset 250nm
Expect 1230E15 photons / second
Remove 40mm at the center



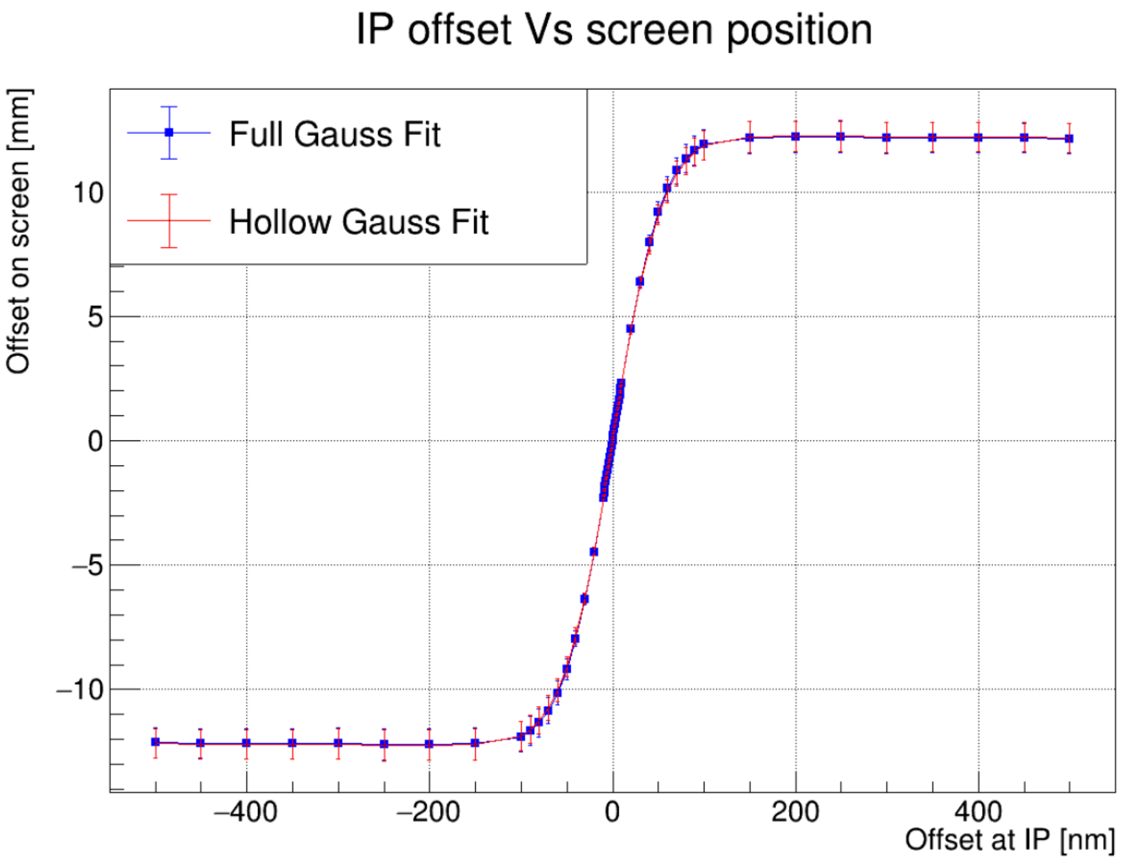
Usefull range of the IP beam to beam distance scan

The displacement of the BS photon peak is happening in a 20 mm range on the screen placed at 400m from IP.

It saturates if the beam-beam distance is greater that 100nm at the IP.

The tracking of the peak position would be most useful only to fine tune the beam-beam distance in the linear region.

RANGE : -50nm to 50nm
Both Full and Hollow fit would work well.
Tested 30mm hollow screen aperture.



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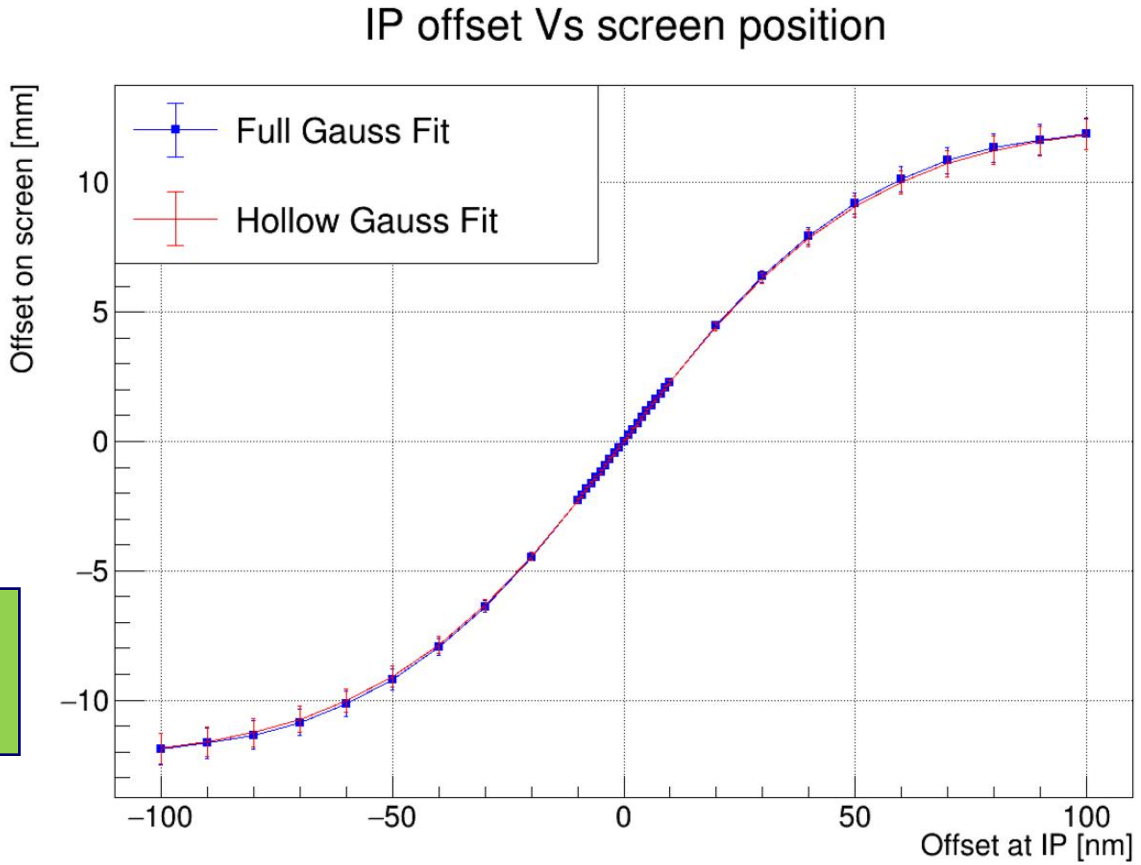


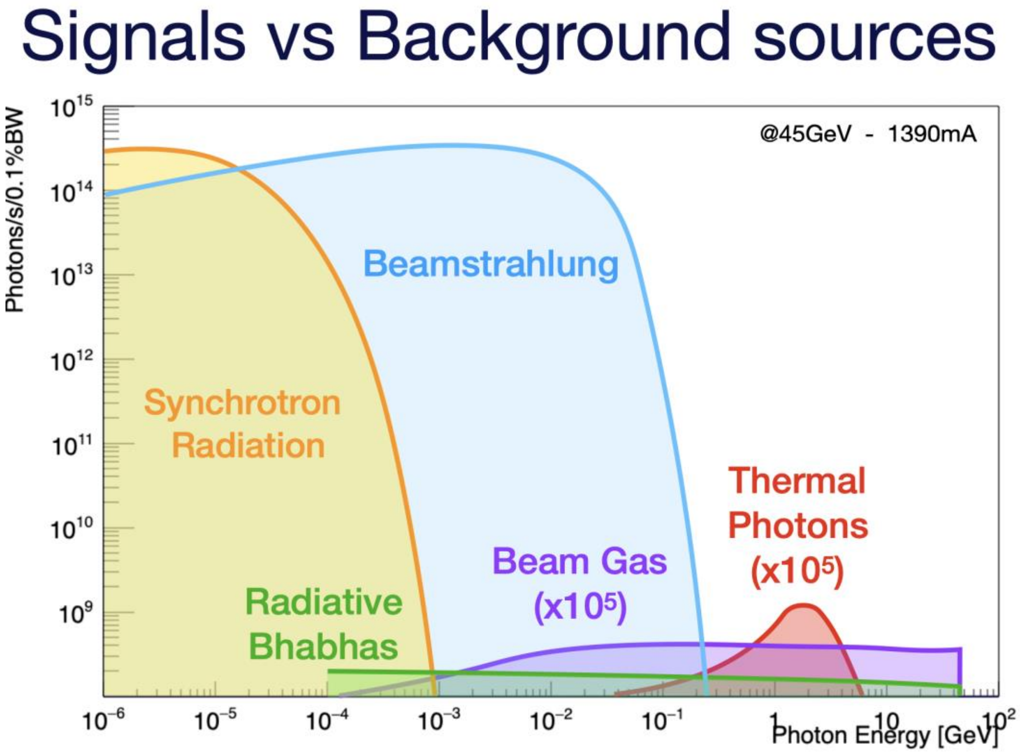
Direct observation in the visible range ?

The Beamsstrahlung spectra should reach down to optical wavelengths.

Another possibility is to use glassy carbon screens (super light weight) to monitor Beamsstrahlung photons in the optical range.

To be evaluated: the quantity of visible photons generated by Beamsstrahlung.

And the BS to SR radiation levels with IP shielding against SR.

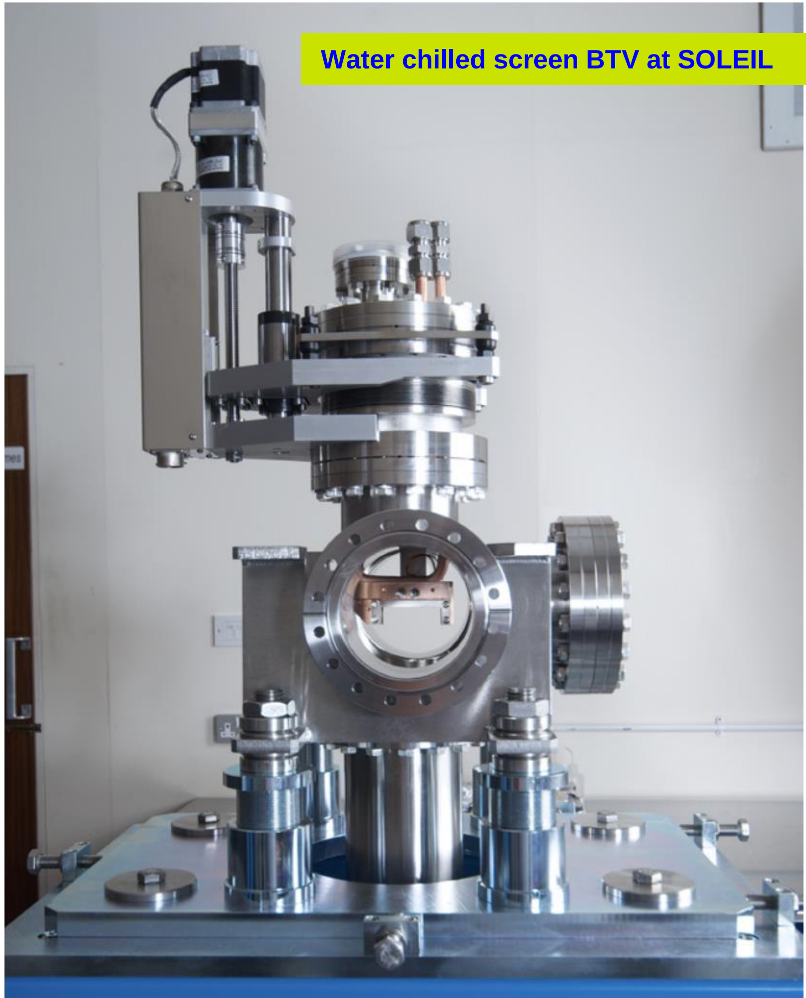


Screen cooling

Screen support can be designed with water circulation pipe for cooling.

Brazing techniques of Chromox screen have been developed in order to increase the heat transfer.

Just need extra interlock and security to make sure the water is well circulating and avoid boiling.



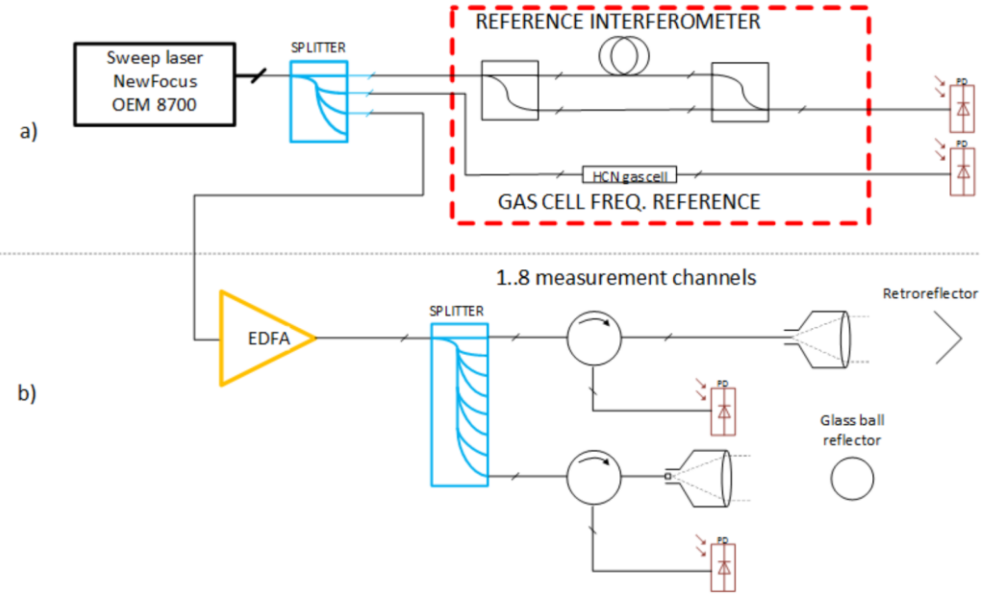
Water chilled screen BTV at SOLEIL

Screen position control

If the precision of the stepper motor control unit is not enough for monitoring of the position of the screens.

We could use Frequency Sweeping Interferometry FSI developed by the CERN to monitor cold mass position in cryostats in harsh radiation environment.

Use a **fiber and remotely located readout** to perform position monitoring.



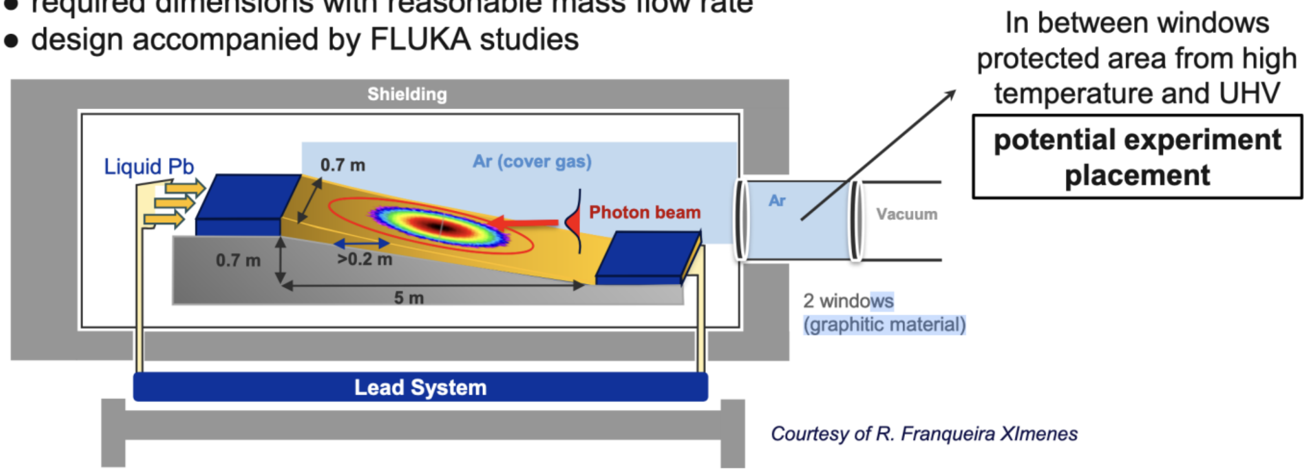
Other option: monitor the BS Profile at the dump

We could image the Cherenkov produced by the secondaries from the first dump exit window. Since they would radiate into the Argon filled compartment.

Implementation of a liquid Pb system

Pure Pb 'slide flow' system under design

- thermomechanical studies showed graphite limitations
- better heat dissipation
- required dimensions with reasonable mass flow rate
- design accompanied by FLUKA studies



Courtesy of R. Franqueira XImenes

Outlook and next steps

- The work on Beamsstrahlung extraction line instrumentation has started.
- A BTV to monitor the Beamsstrahlung peak position seems feasible. This technique will integrate the full beam. The scintillation relaxation time does not allow bunch by bunch. Need to evaluate thermal dissipation of the screen.
- Experimental test would be needed to evaluate screen material with MeV range gammas, to make sure about the expected SNR ratio between SR and BS
- A better knowledge of the SR contamination in the Beamsstrahlung channel is needed.
- Next step would be to evaluate the BhaBha beam-loss intensity on a bunch by bunch basis. If it proves to be of interest for the IP tuning.

Thank you
for your attention.

Statistics and bias

To evaluate the effect of aperture on the fit I performed statistical studies.

Conclusion:
The IP tuning scan should be performed in two steps

- First with only a few colliding bunches in the machine and a full BS screen inserted in that case we can scan from -1um to 1um with expected BS peak power at 250nm
- Second a small range scan with the full beam load over a -50nm +50nm range

This scheme would allow to reduce the peak power deposited into the screen and maximise precision

Cooled Fluorescent Screens

Slide from SOLEIL light source

Screens generally consist of a fluorescing material or coating supported on a water-cooled actuator being inserted into the synchrotron beam. Viewing devices, typically CCD or CMOS cameras are positioned to view the illuminated area to determine the beam size and shape, with the vacuum assured by a non-discolouring viewport.

The standard screen materials used are CVD Diamond (for high power densities) and Yttrium Oxide.

Typically pneumatic actuators are provided for use with screens however certain applications, e.g. beam movements, dictate the use of motorized actuators fitted with incremental encoders.