# Diffraction Radiation test at Cornell

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3. Cornell University, Ithaca, New York, USA

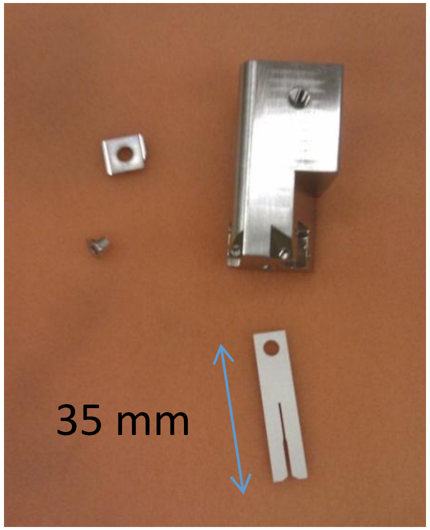
# Goals of Phase 1 test:

To test all hardware designed and assembled at CERN:

- Installation of the ODR tank
- Control of target mechanism and replacement chamber mechanism
- Image acquisition using optical system

To establish a procedure to align the electron beam to pass through the dummy target aperture.

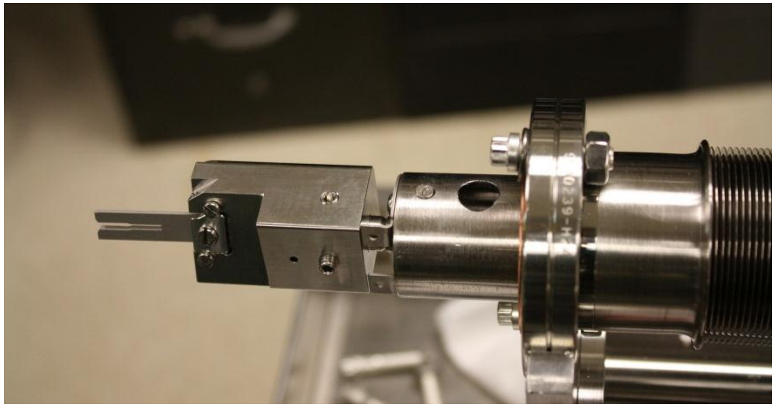
# Dummy Target

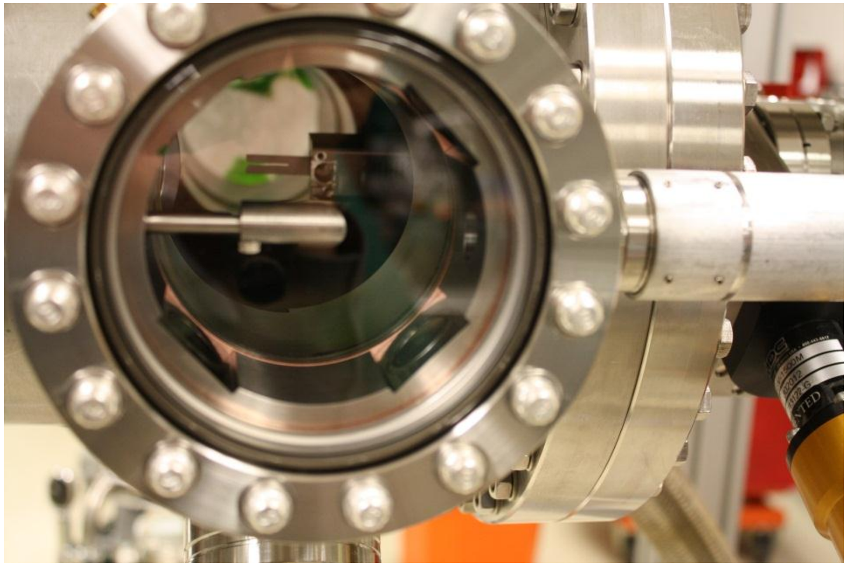


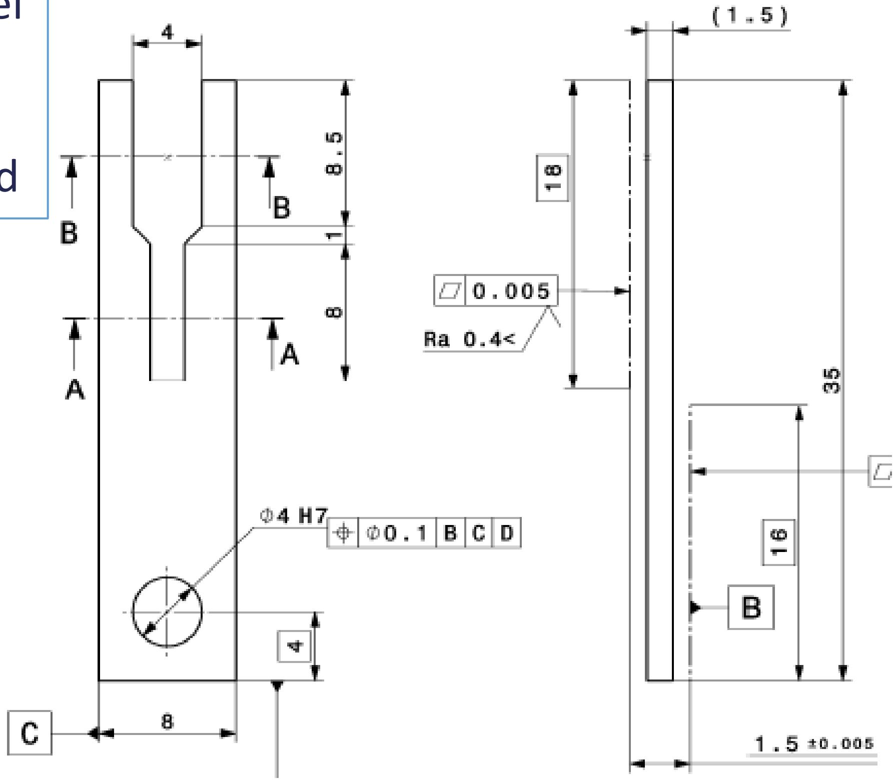

Aperture sizes:
2 mm and 4 mm
(etched)

Material: Stainless steel

Note: This dummy target was not polished

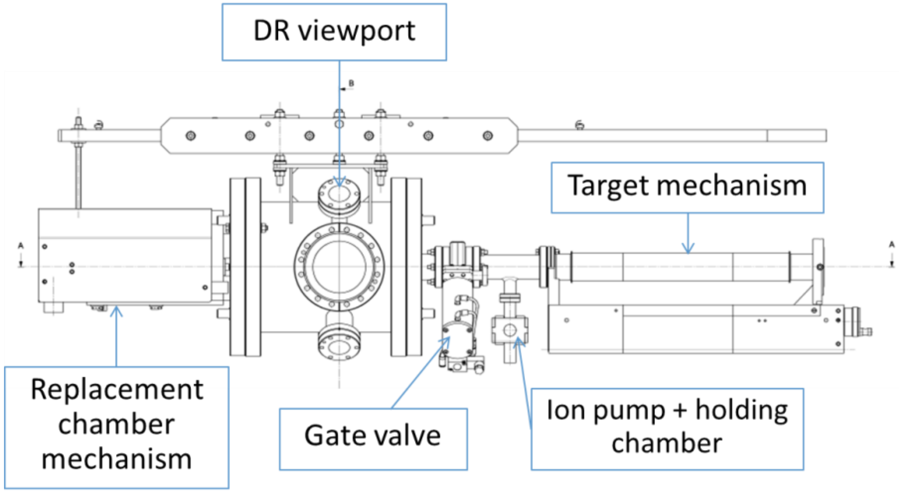


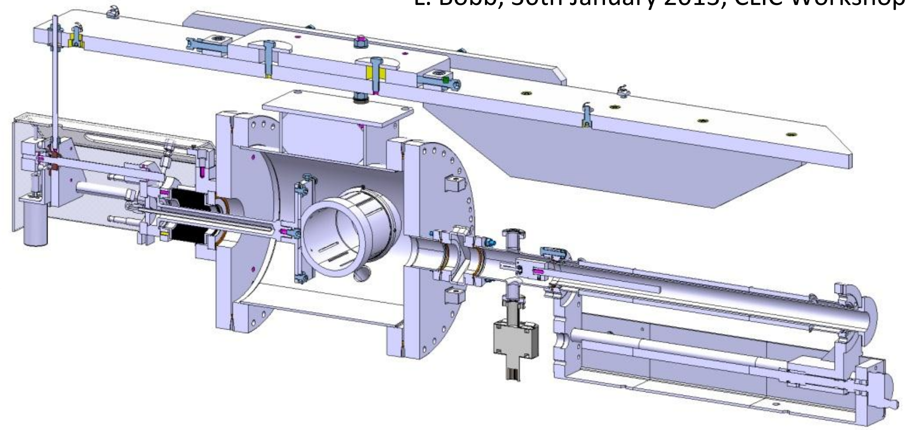


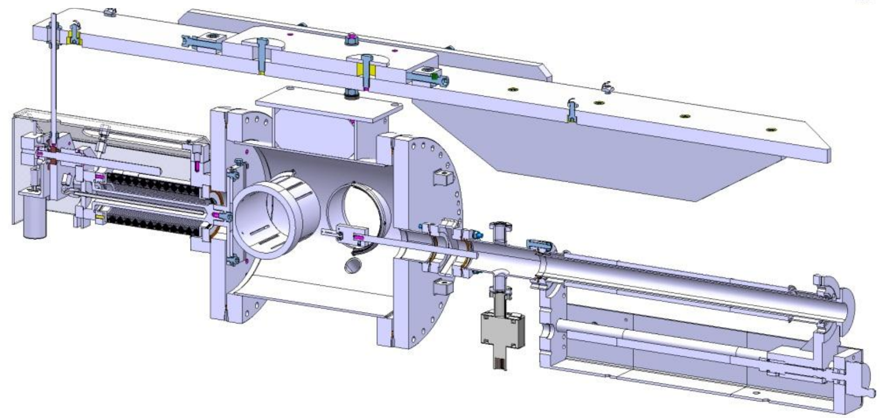



*Technical drawings by N. Chritin*
*Images by Y. Li*

# Vacuum chamber assembly

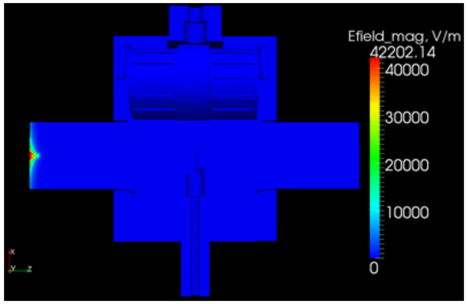


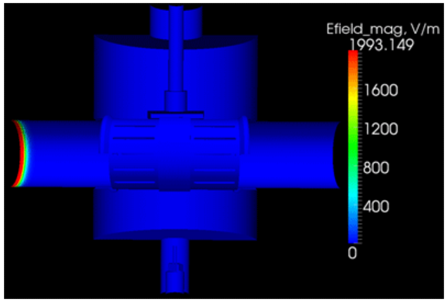





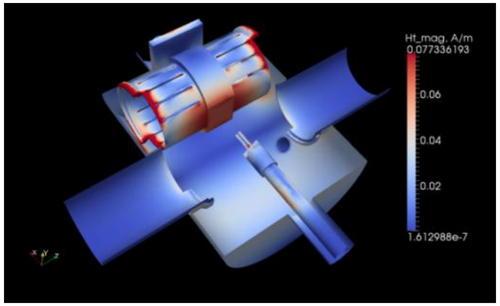
*Technical drawings by N. Chritin*
*Simulations by A. Nosych*

**E-field magnitude of a single bunch pass in time domain (Gaussian bunch, length = [-4σ,4σ], σ = 10mm)**



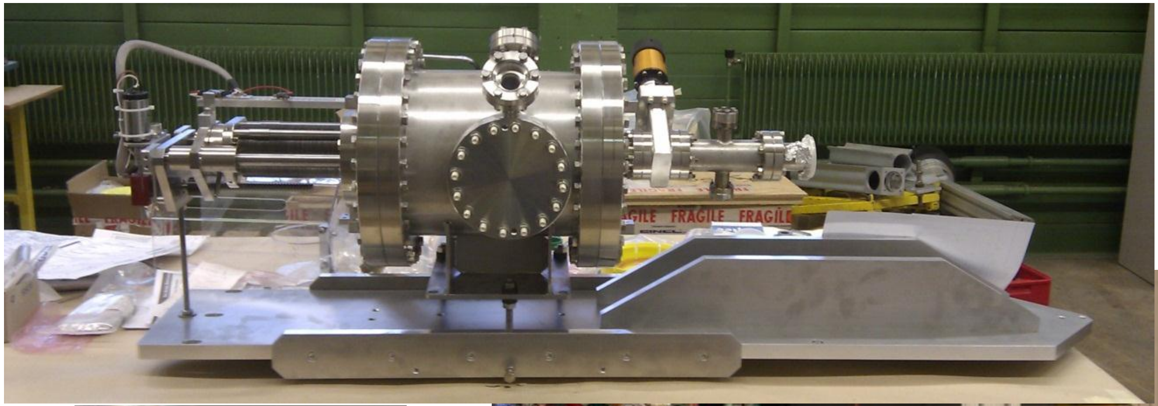




**H-field surface tang complex magnitude (Loss map)**
**Mode Fr = 1.19 GHz, Q = 3309, Ploss = 0.075 W**

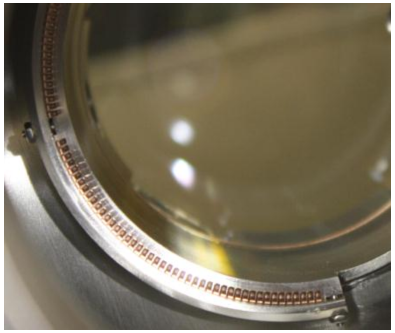


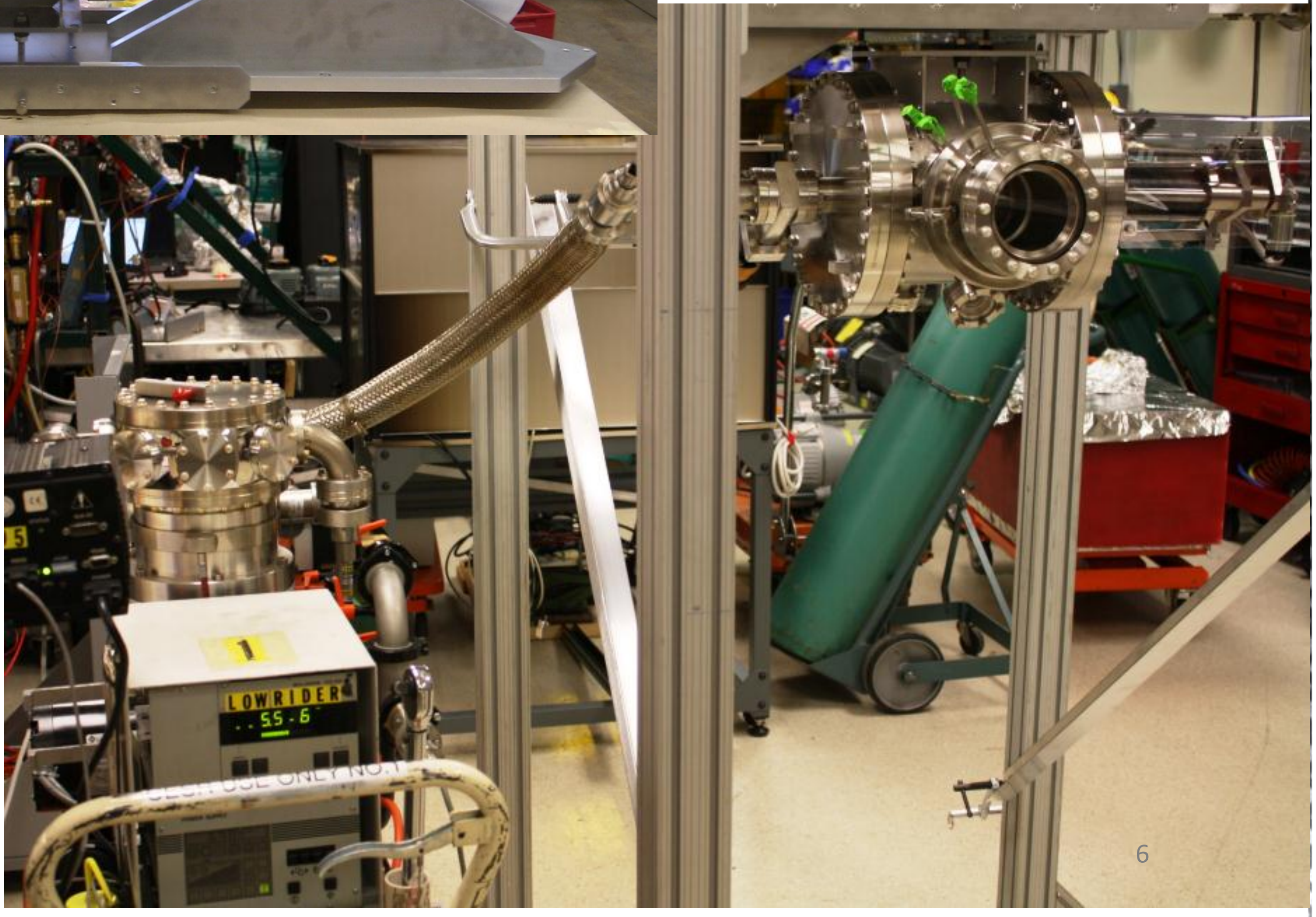

**Total power loss for single bunch = 0.6 W**

# Vacuum chamber assembly cont'd



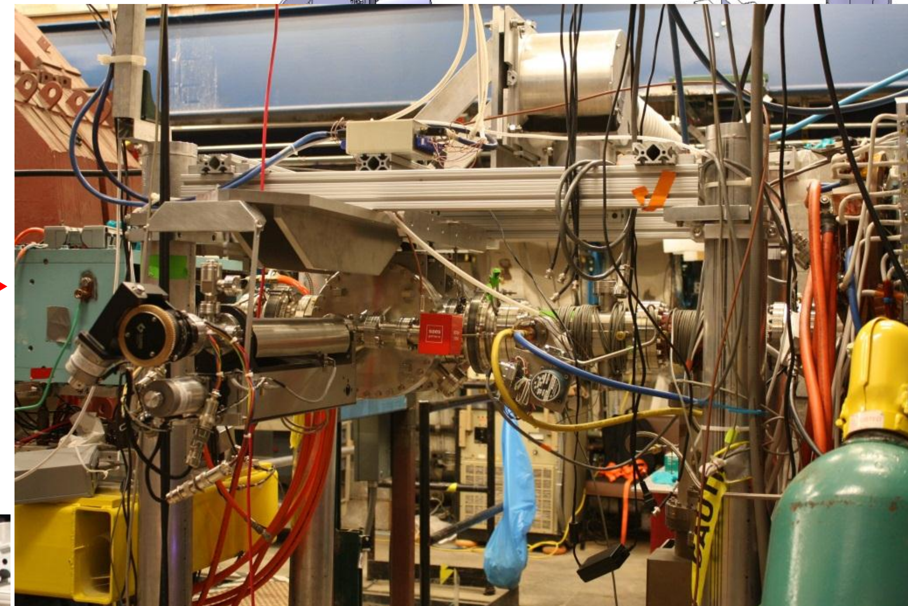

Images taken during assembly at CERN and current testing at Cornell.

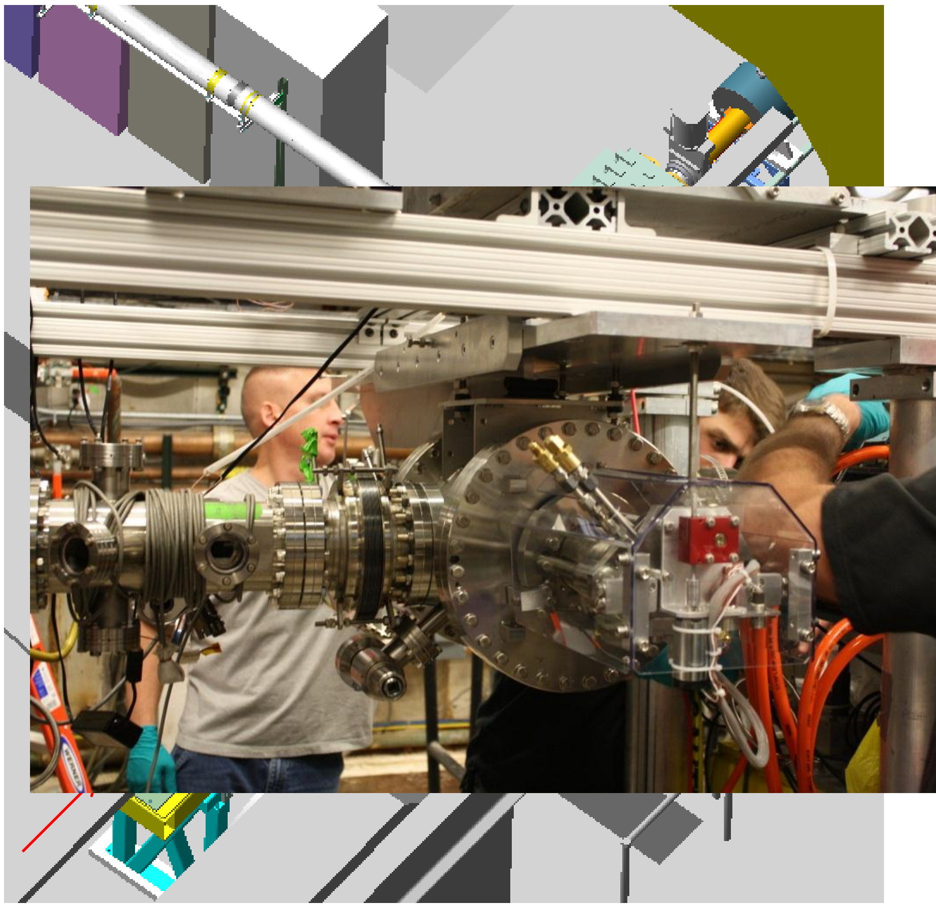




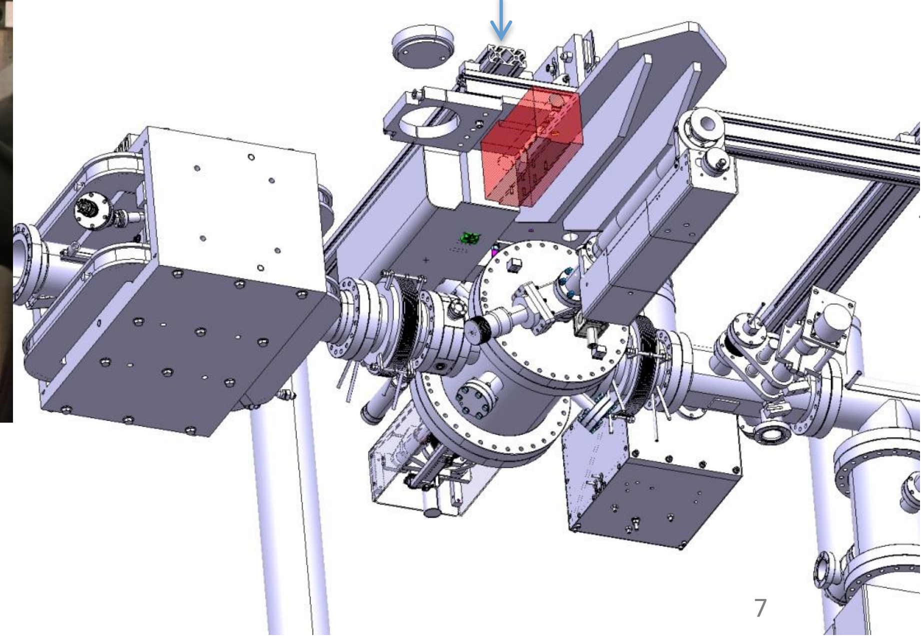
# L3 layout @CesrTA

Electron beam direction



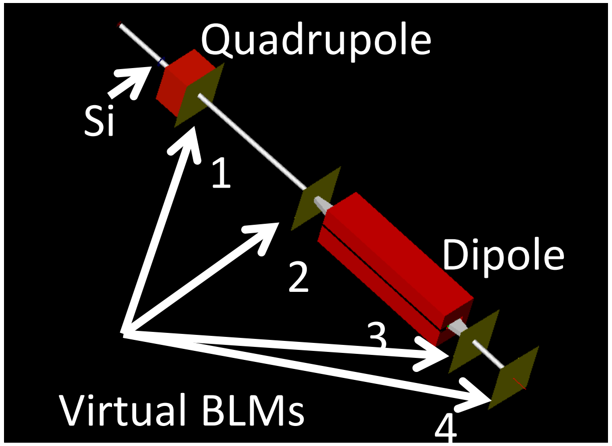


DR experiment

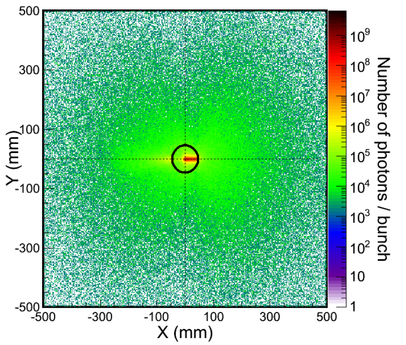


*Technical drawings by N. Chritin*

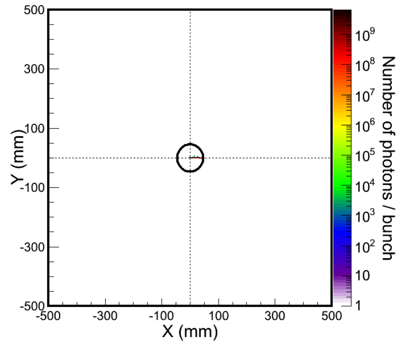
# Method of Operation



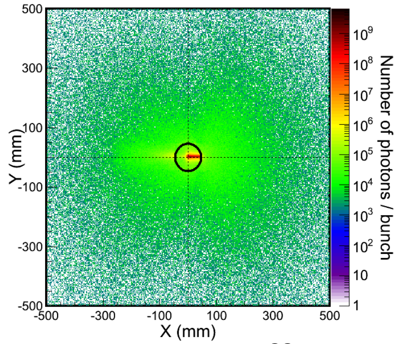

1. Alignment of the electron beam with the target aperture:
   - BPMs for centering
   - Target imaging to look for OTR from beam halo
   - Correlate with BLMs:




-400μm off



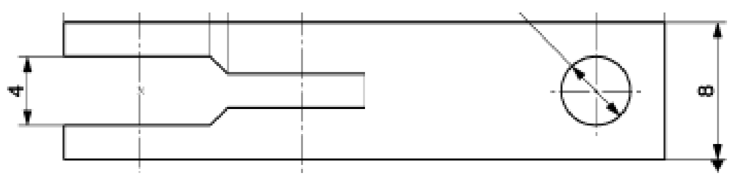

center




+400μm off

Virtual Detector 3

Single bunch of electrons



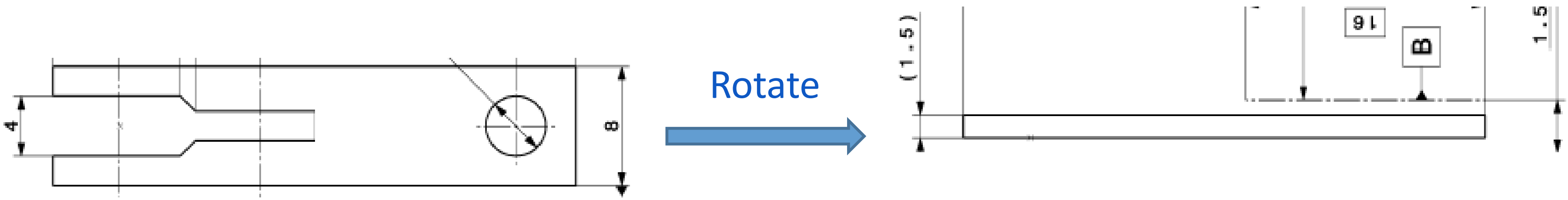

Gradually move target in

*Simulations by A. Apyan*

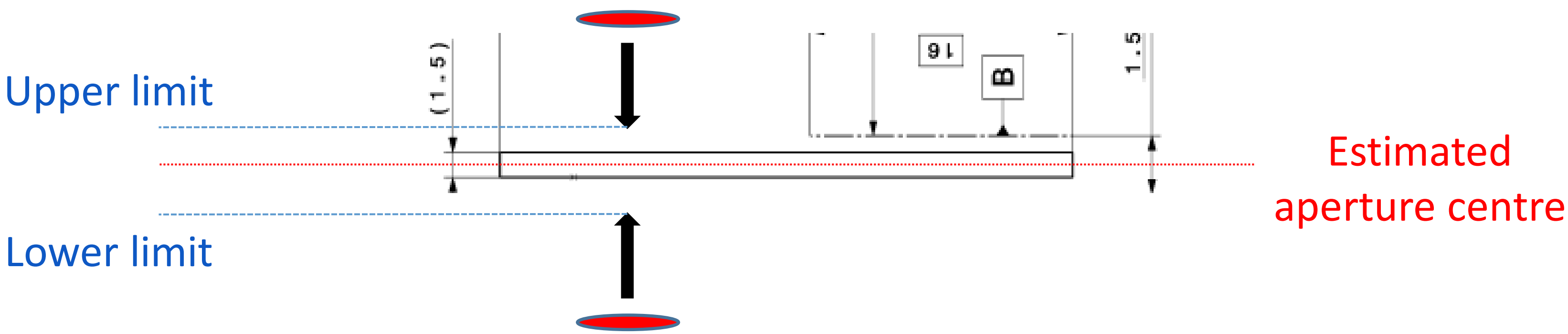
# Method of Operation cont'd

To find the position of the aperture centre:

1. Rotate the target such that the aperture is in the horizontal plane. (Centre of rotation at aperture centre).




2. Adjust the beam vertical position to approach the target from above.



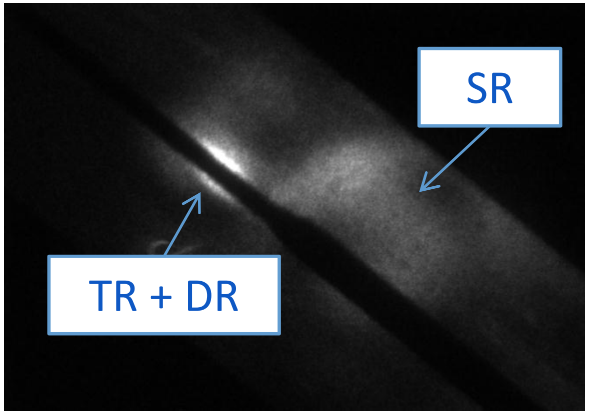

3. Record the vertical position BLMs pick up beam scattering.
4. Repeat steps 2 and 3 starting with the beam below the target.
5. Take the average of the 2 recorded positions as the aperture centre.

# Results

Beam lifetime much shorter than expected (approx. 2-3 mins)

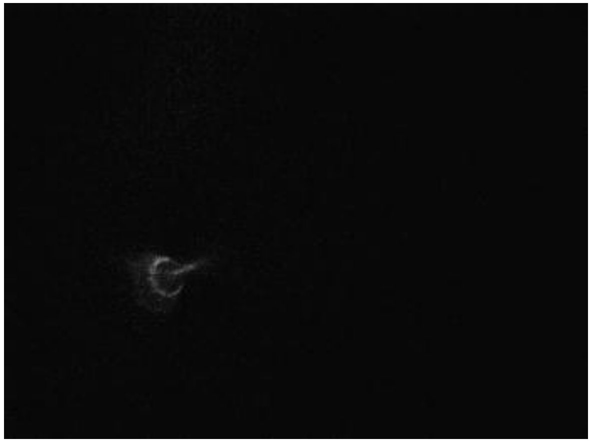
Start-point camera acquisition details:
12bit
camera exposure time: 15 ms (approx. 5860 turns)
camera gain: 10
Intensifier: open
Intensifier gain: 2V

| target slit size [mm] | vertical beam size [µm] | beam lifetime [min] |
|---|---|---|
| 0.1 | 9.2 | 2.40 |
| 0.5 | 30 | 60 (max) |
| | 50 | 2.22 |
| 1.0 | 50 | 60 (max) |



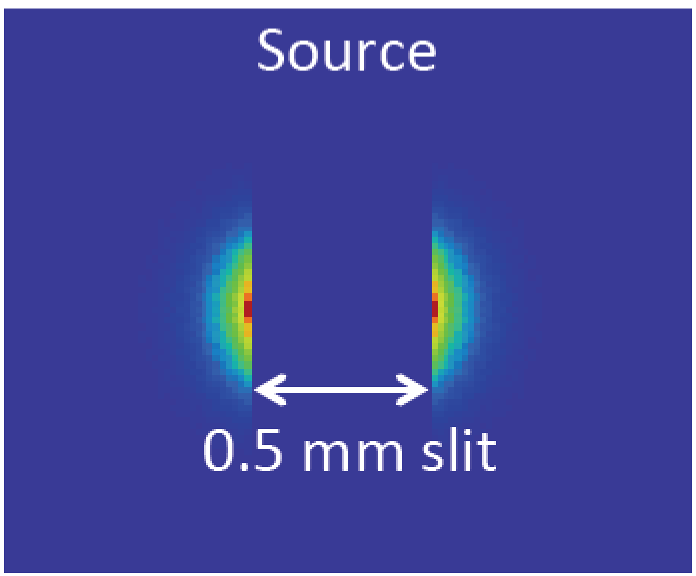

1mA single bunch (injection 7; 2.1 GeV)

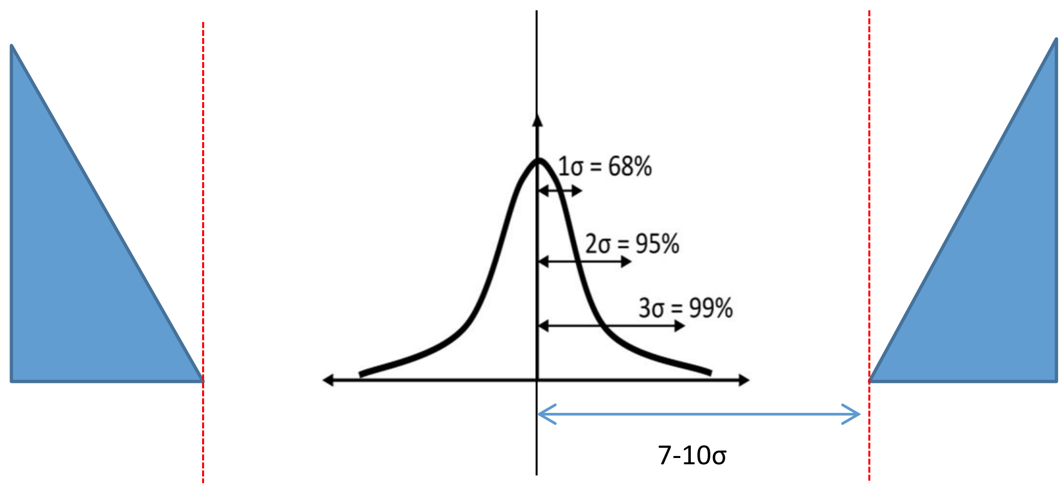
2 mA 10 bunches (injection 8; 2.1 GeV)



# Results cont'd

- Investigation into the shorter than expected beam lifetime is on-going:
  - xBSM was not available during our machine studies at CESR. Before breaking vacuum for installation $\sigma_y \sim 50\ \mu m$.
  - Vertical beam scraper results from Cornell have indicated the beam size was much larger than expected possibly due to beam-gas scattering from breaking vacuum during installation.

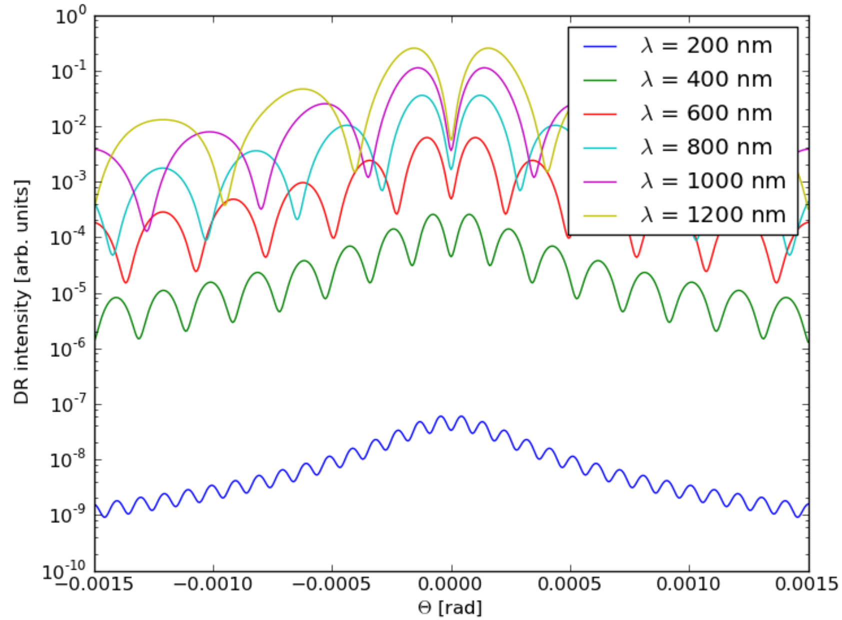


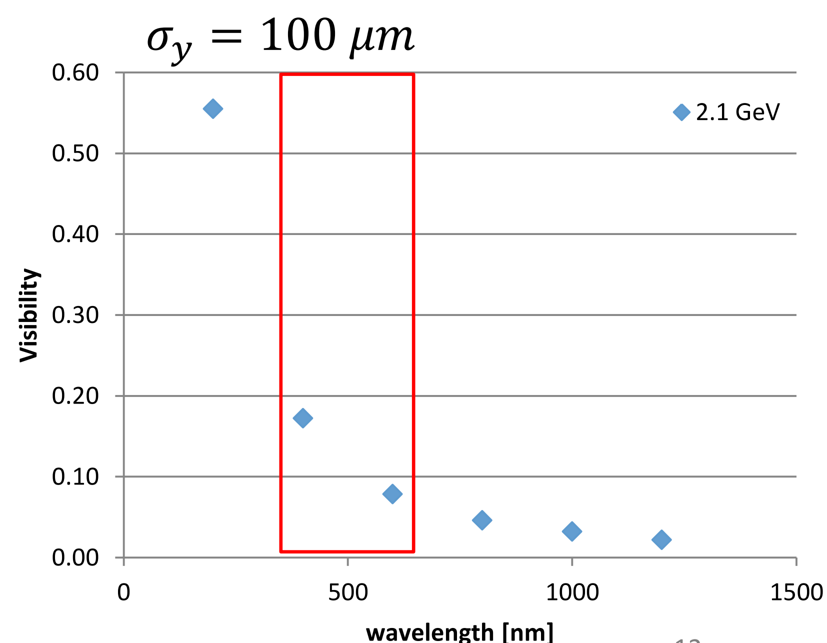




Requirement for sufficient beam lifetime

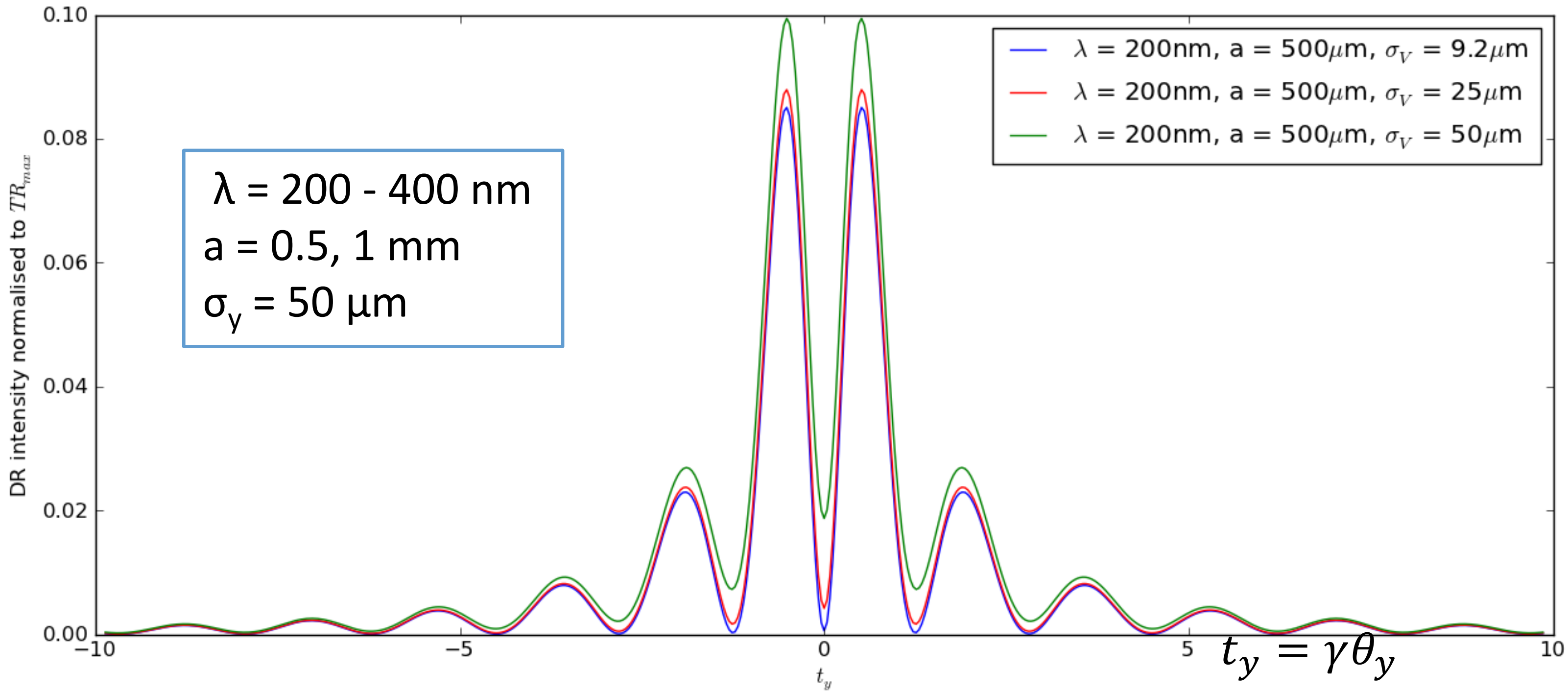
# Outlook

- Target metrology
- Redesign of target holder to prevent drooping
- Survey of L3 straight section
- From the location of SR relative to the TR + DR fringes observed we can improve our set-up for the next experimental test e.g.
  - Since intensity scales with the reflection coefficient of the target, to use a matt surface over the SR region and a polished surface around the 2mm aperture.
- Select the best wavelength to intensity and visibility ($I_{min}/I_{max}$) compromise for beam size measurements.
- Quantitative analysis of images acquired from December test- in particular the ratio of SR to TR+DR.



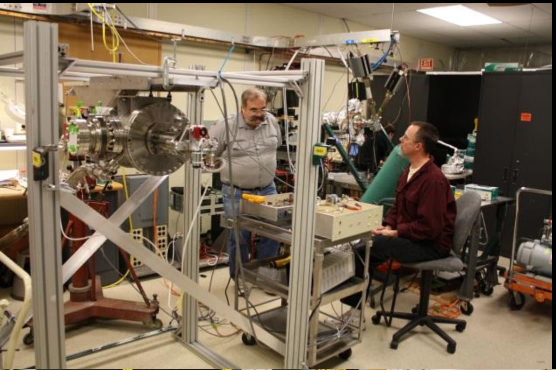
# Outlook cont'd

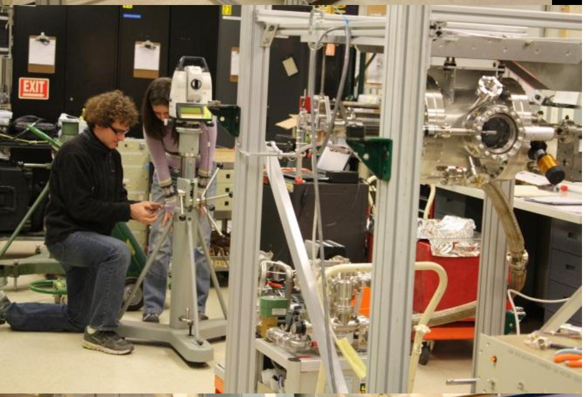


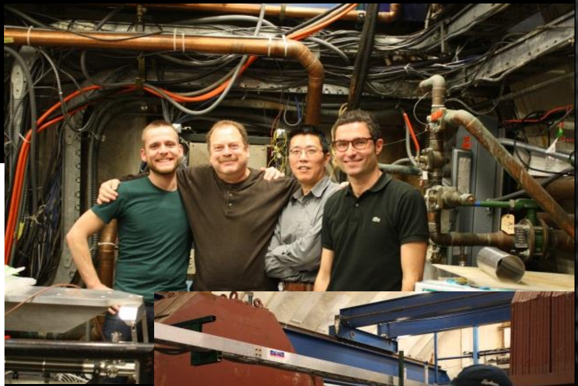
# Conclusion

- ODR tank, optical system, mechanisms and controls were all installed and tested successfully.
- Using information provided by beam lifetime, BPMs, BLMs and target imaging diagnostics allowed we could establish an alignment procedure.
- Electron beam passed through both the 2 mm and 4 mm apertures as required.
- Work is on-going for combining the analytical equations of DR with the physical optics of Zemax.
- Next step is to prepare for April 2013 test to measure beam size $\sigma_y$.

# Acknowledgements







CERN:
A. Apyan, S. Burger, N. Chritin, A. Jeff, O.R. Jones, A. Nosych, S. Vulliez

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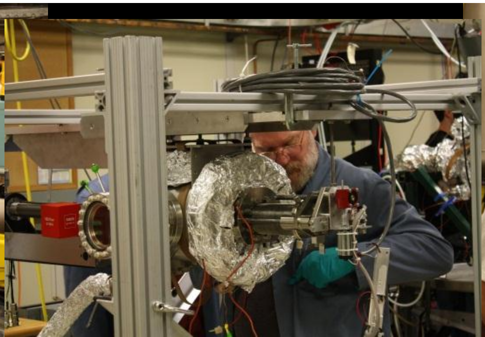
J. Barley, J. Conway, J. Lanzoni, Y. Li, T. O'Connell, M. Palmer, D. Rice, D. Rubin, J. Sexton, J. Shanks, C. Strohman, S. Wang

Members of CERN main workshop, BI workshop and CESR

BE-BI/PM

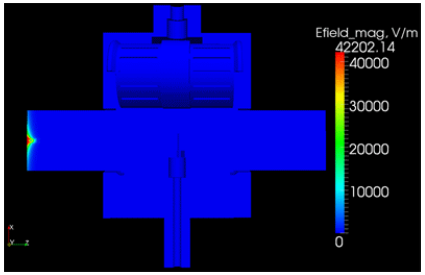
Thank you for your attention

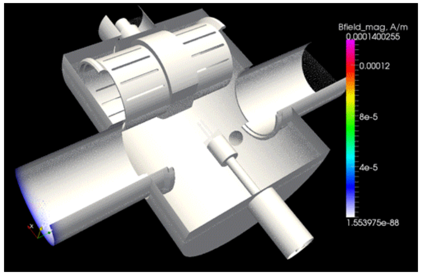
Questions?

Extra slides

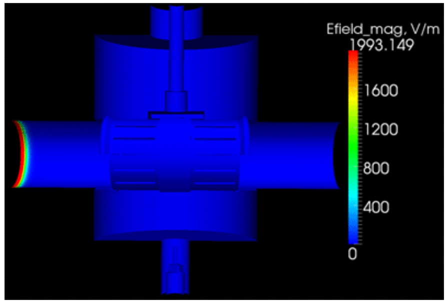
# Higher Order Modes (HOMs)

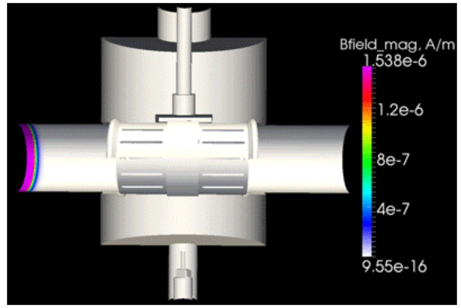
**E-field + B-field magnitude of a single bunch pass in time domain (Gaussian bunch, length = [-4σ,4σ], σ = 10mm)**

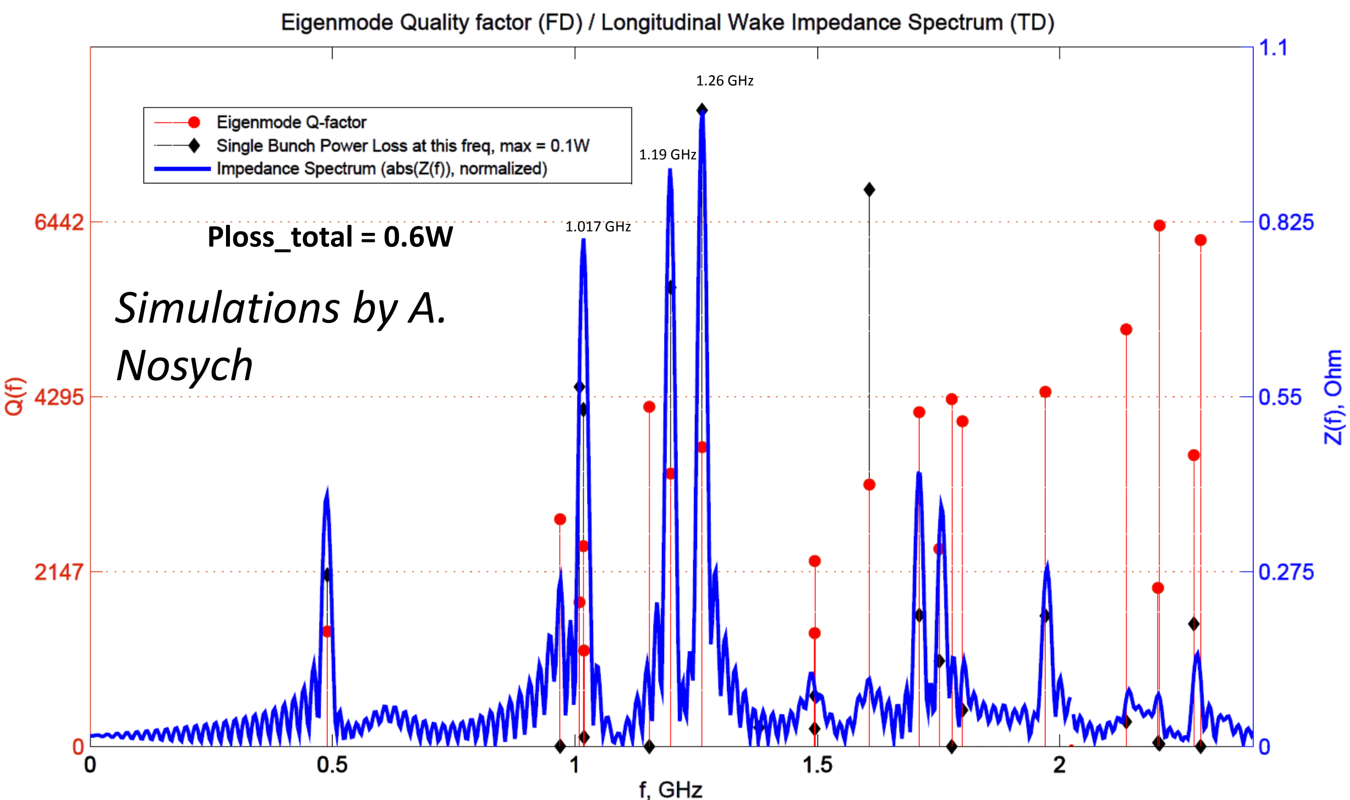


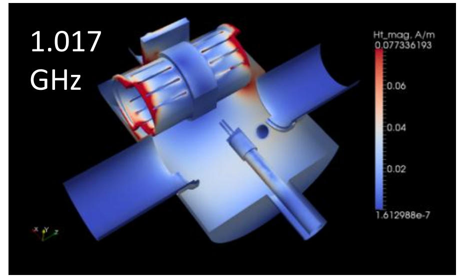

**Fork OUT, Chamber IN**

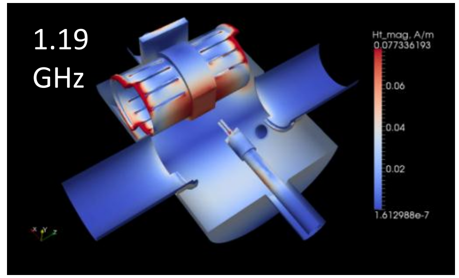


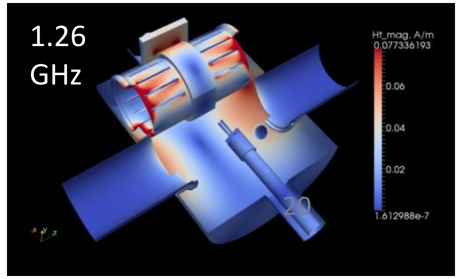




**H-field surface tang complex magnitude (Loss map)**



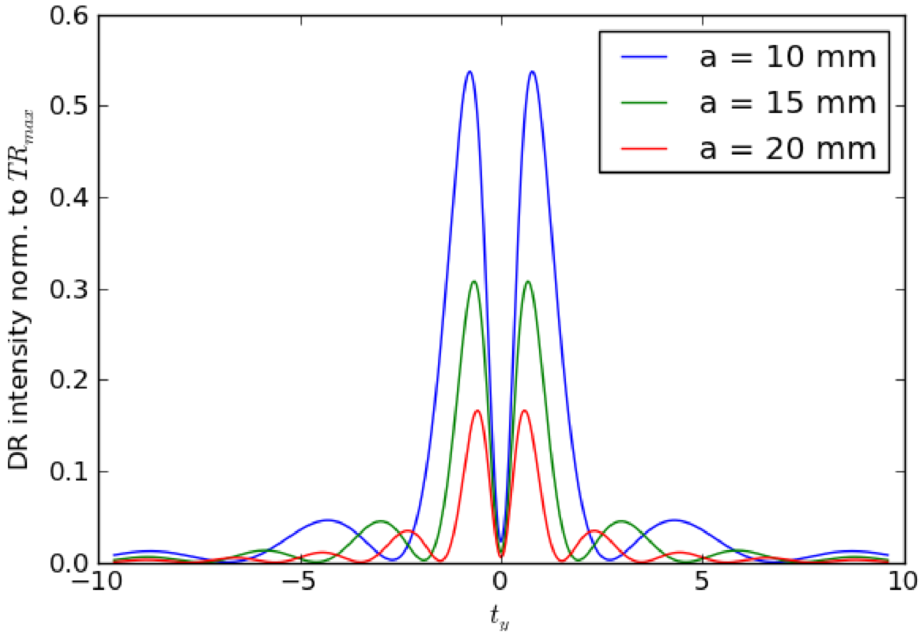
# Feasibility of a ring beam size monitor

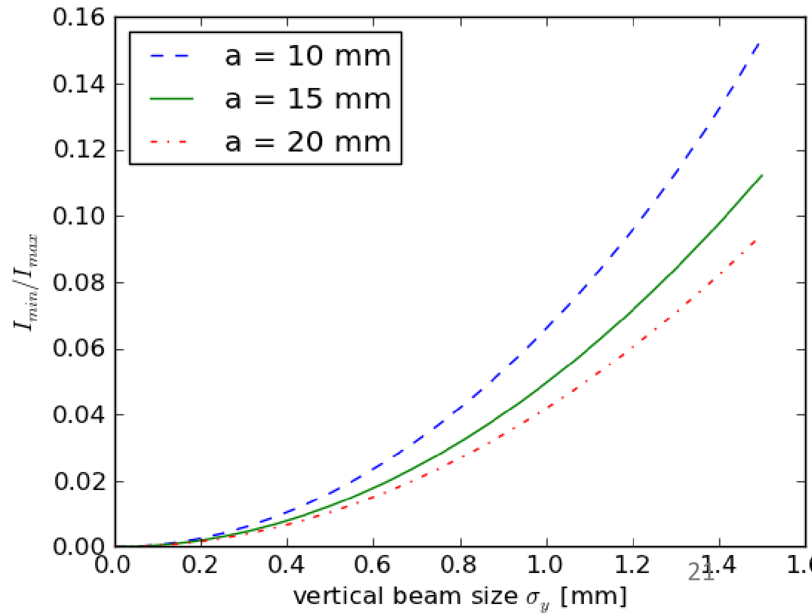
- LHC also has γ ≈ 4000 (@ E = 4000 GeV)
- Using proton beam:
  - Reduced SR background
  - Larger beam size
- Wavelengths in the infrared spectral range

Main requirement:
Non- invasive measurement

↓

Must use large target aperture

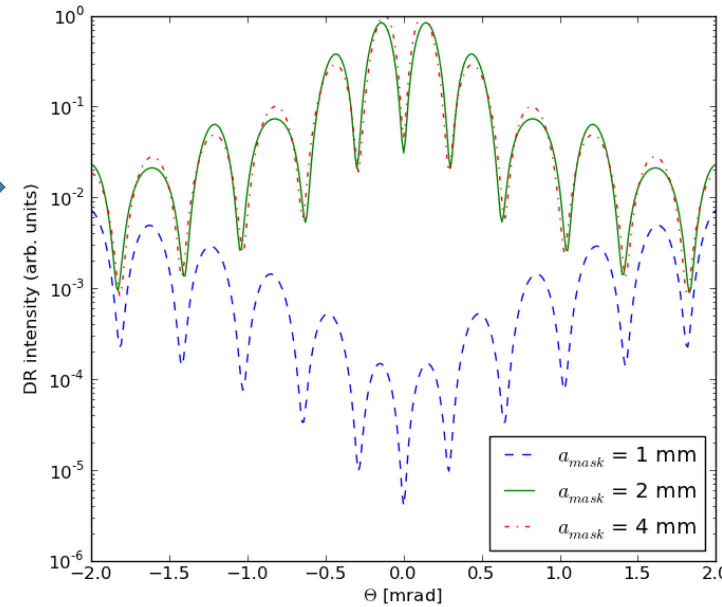


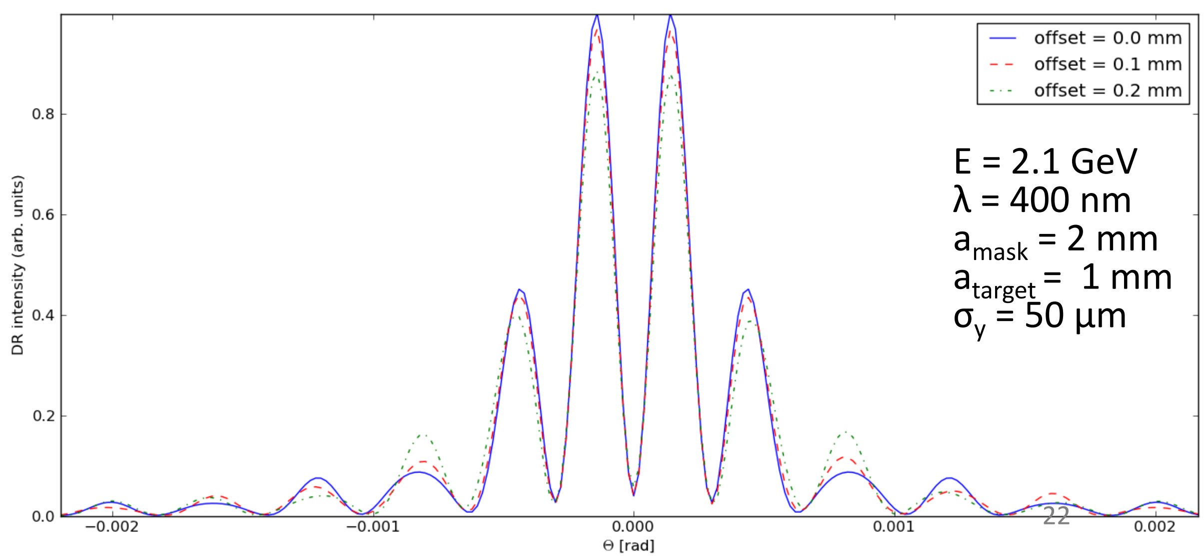
# Optical Diffraction Radiation Interference (ODRI)

*A. Cianchi et al., Phys. Rev. ST Accel. Beams 14 (10) 102803 (2011)*

| Aperture sizes | Interference |
|---|---|
| $a_{mask} = a_{target}$ | Complete destructive interference of FDR + BDR (blue) |
| $a_{mask} \approx 2 \cdot a_{target}$ | Measureable interference (green) |
| $a_{mask} \geq 4 \cdot a_{target}$ | Negligible interference (red) |

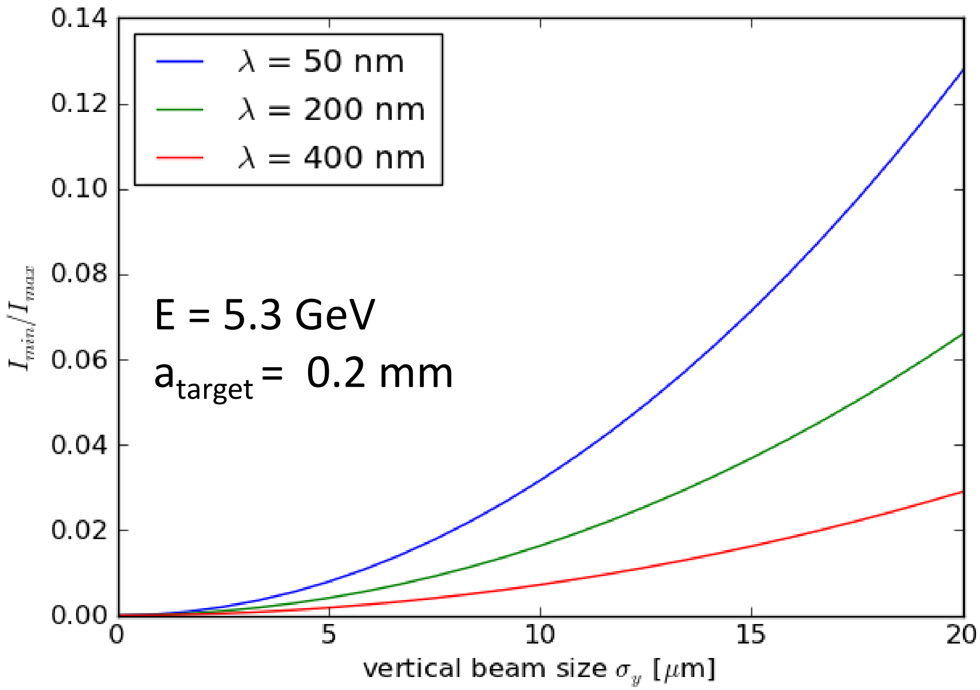



Using non-collinear slits (i.e. centres of mask + target do not coincide) allows measurement of beam size, beam offset from the target centre and angular divergence.



# Phase 2: Micron-scale resolution

- DR at soft X-ray wavelengths:
  - More complex optical system.
  - Grazing target tilt angle
- Aperture size determined by impact parameter for given wavelength




Main requirement:
Micron-scale resolution

Must use shorter wavelengths

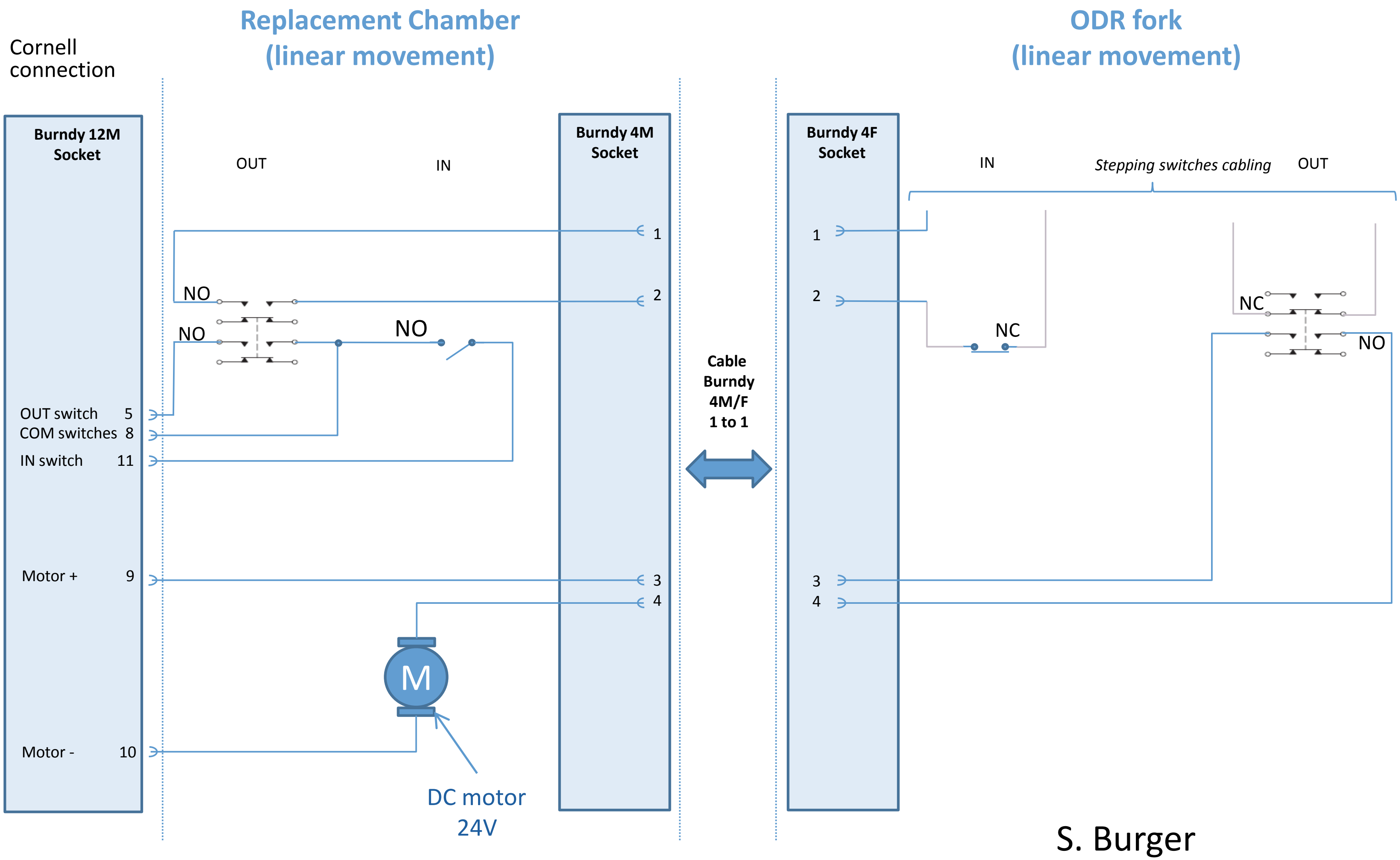
Sensitivity @50 nm ≈ 2x sensitivity @200 nm

# ODR movements

- There are 2 stepping motors:
  - 1x linear movement of the fork
  - 1x angular movement of the fork
- There is 1 DC (+24V) motor that drives a linear movement for the replacement chamber
- The linear (stepping) movement of the fork and the linear (DC) movement of the replacement chamber have to be interlocked one with respect to the other to avoid collision (see next slide)
- Cabling of stepping motors has to be adapted  to available driver (unipolar/bipolar) (tests @ CERN were performed with bipolar driver and cabling)



S. Burger




Hardware INTERLOCK logic: ODR fork can not move if replacement chamber not OUT
Replacement chamber can not move if ODR fork not OUT

# Interlock ODR movement

*(as connected with CERN screen instrumentation 'standard' driver)*

*Stephane.burger@cern.ch*

# Optical System

**Far-field Condition:**

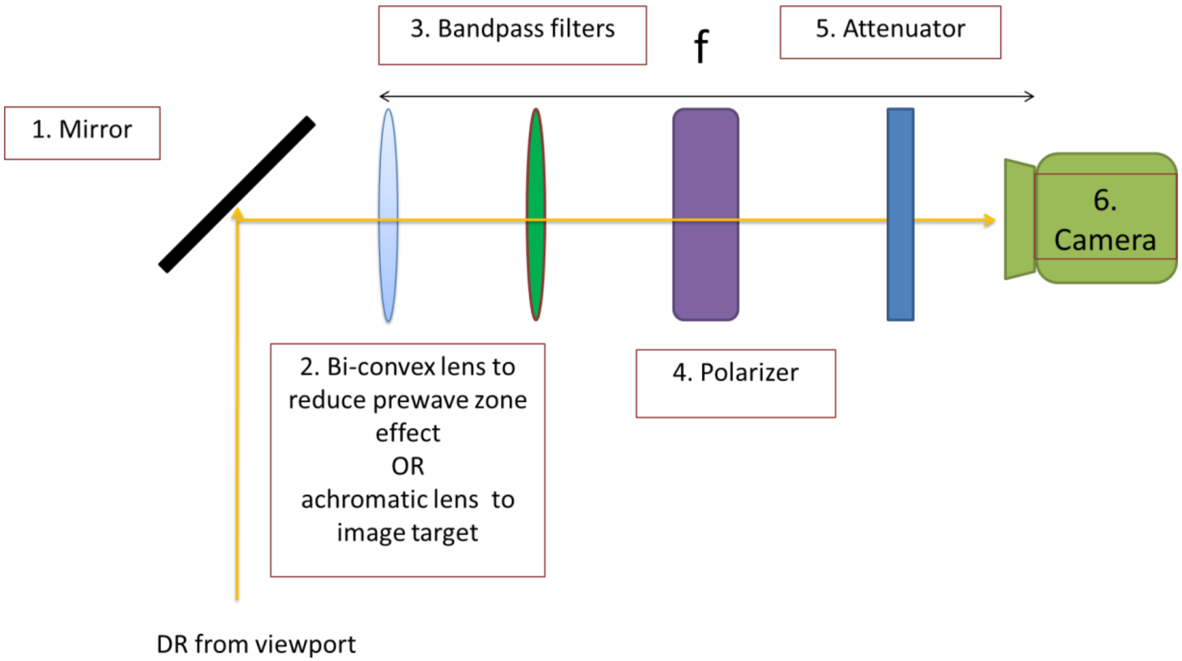
$$L \gg \frac{\gamma^2 \lambda}{2\pi}$$

- L = distance from source of DR to detector.
- Compact optical system is in the prewave zone

(*Pre-wave zone effect in transition and diffraction radiation: Problems and Solutions* -P. V. Karataev).

$\frac{\gamma^2 \lambda}{2\pi}$ given γ and λ:

| | 2.1 GeV | 5 GeV |
|---|---|---|
| **200 nm** | 0.54 m | 3.18 m |
| **400 nm** | 1.08m | 6.37 m |




| Compact optical system (distance to detector $L \leq \frac{\gamma^2 \lambda}{2\pi}$) | Long-range optical system (distance to detector $L >> \frac{\gamma^2 \lambda}{2\pi}$) |
|---|---|
| Bi-convex lens required with camera in back focal plane. | Far-field zone |
| Dual purpose: 1. Image target 2. Image DR angular distribution | |
| DR observation wavelengths: λ = 200 nm, 400 nm | |
| In footprint of target mechanism ( < 1m) | Determined by L and spatial constraints. |