ChDR ATF2 monitor status and upgrade plans

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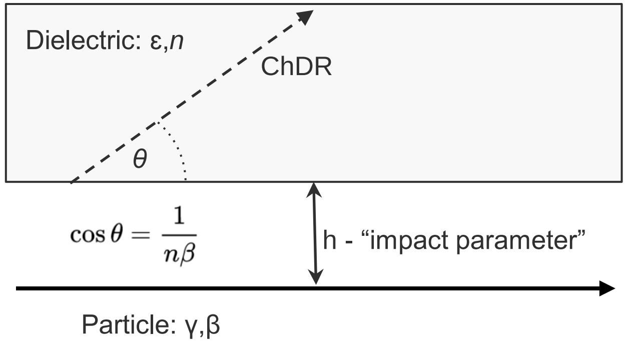
Cherenkov Diffraction Radiation (ChDR)

The electric field of ultra-relativistic charged particles passing in the vicinity of a dielectric radiator produces photons by the Cherenkov mechanism (polarization effect).

- Large emission angle: $\cos(\theta_{Ch}) = \frac{1}{\beta n}$
- Photons emitted along the target



For cylindrical geometry:

Cherenkov emission – spectral angular

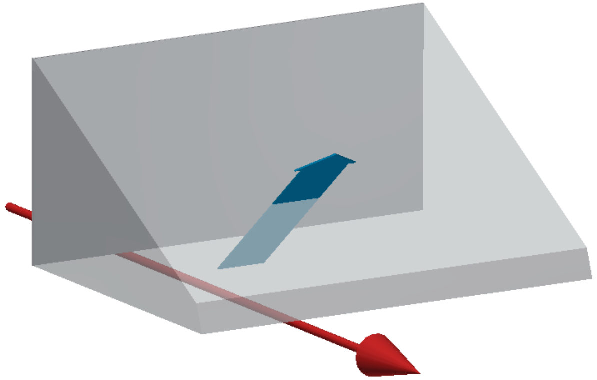
Exponential decay of the particle field

$$\frac{d^2 N_{Dcph}}{d\Omega d\lambda} = \frac{\alpha n}{\lambda}\left(\frac{L}{\lambda}\right)^2 \left(\frac{\sin\left(\frac{\pi L}{\beta\lambda}(1-\beta n\cos\theta)\right)}{\frac{\pi L}{\beta\lambda}(1-\beta n\cos\theta)}\right) sin^2\theta \; e^{\left(-4\pi\frac{h}{\gamma\beta\lambda}\right)}$$

α, fine structure constant
β, normalised beam velocity
γ, beam relativistic factor
θ, angle of observation
L, radiator length
n, index of refraction
h, impact parameter

ChDR in realistic geometries

a) 

b) 

In real accelerators, dielectrics emitting ChDR will be elements embedded in beam pipe walls (a) or prisms (b)

- non-cylindrical geometry
- finite length

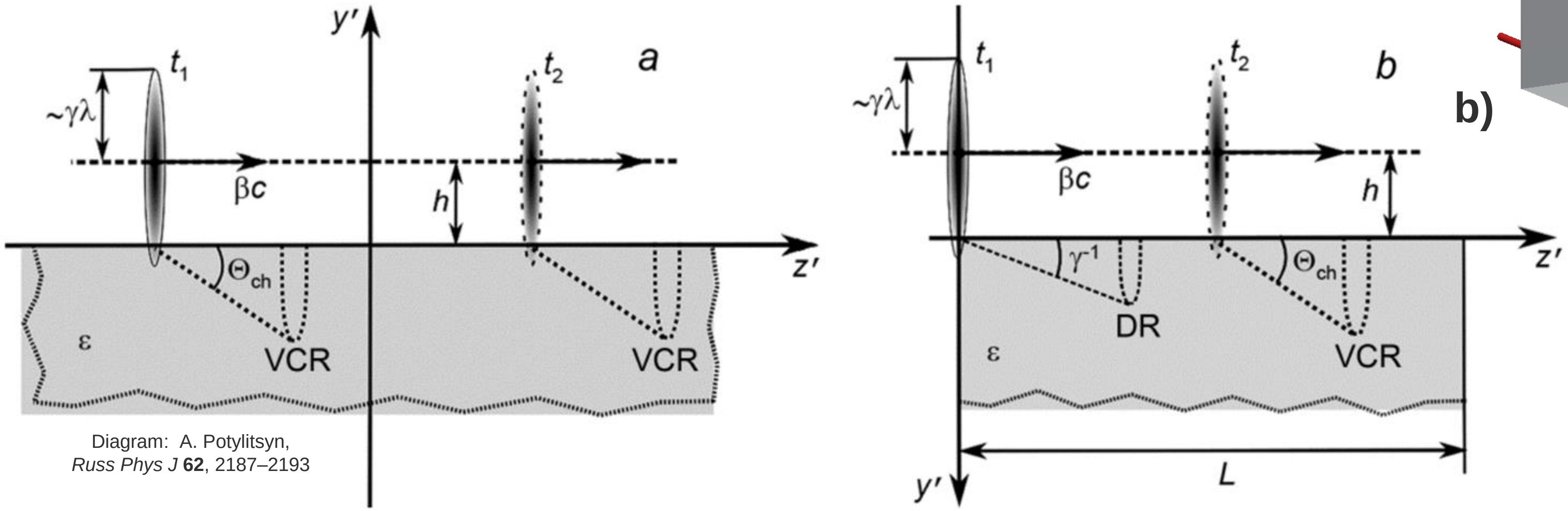


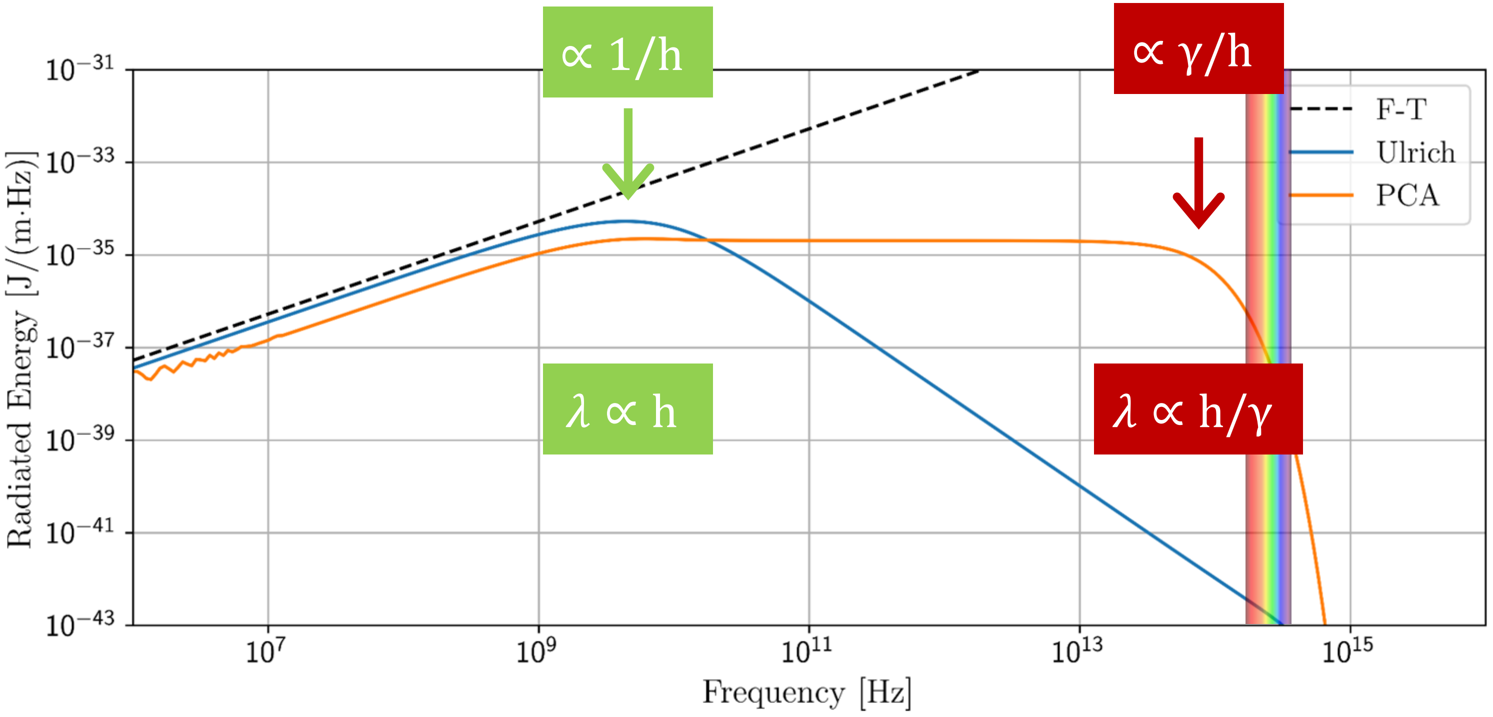
Diagram: A. Potylitsyn,
Russ Phys J **62**, 2187–2193

1 B.M. Bolotovskii, Sov. Phys. Usp. 4 781 (1962).
2 Ulrich, Z. Physik 194, 180–192 (1966).
3. H. A. Olsen and H. Kolbenstvedt, Phys. Rev. A, vol. 21, Jun 1980.
4. Karlovets, D.V., Potylitsyn, Jetp Lett. 90, 326 (2009).

ChDR light yield: not measured to date!

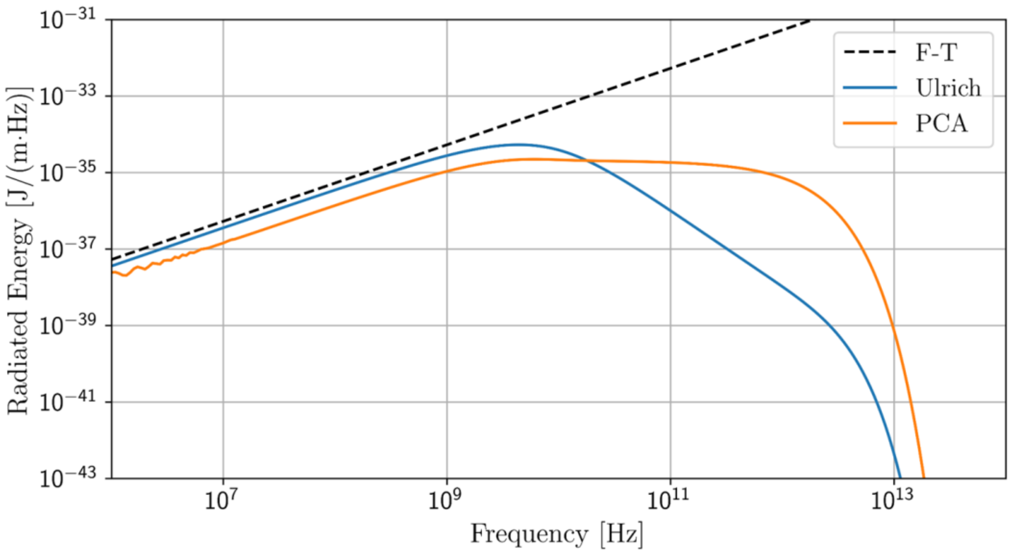
ChDR has a potential for longitudinal diagnostics for high energy future colliders (CLIC, ILC, FCCee), but models predict large differences in photon yield and impact parameter dependence (1/h vs $1/h^3$)

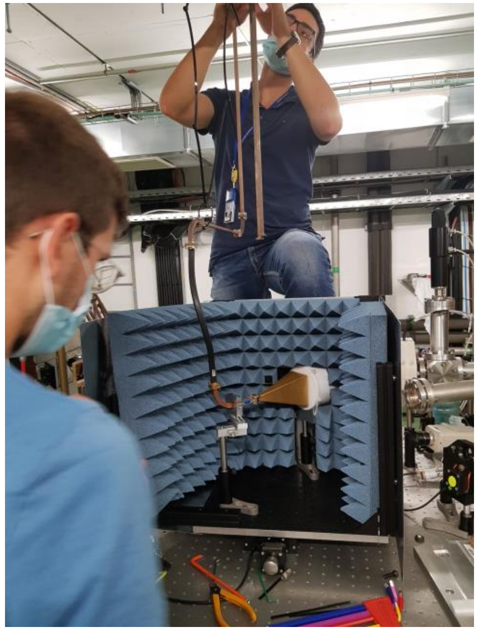
FCC ee Z (45 GeV)
h = 1 cm

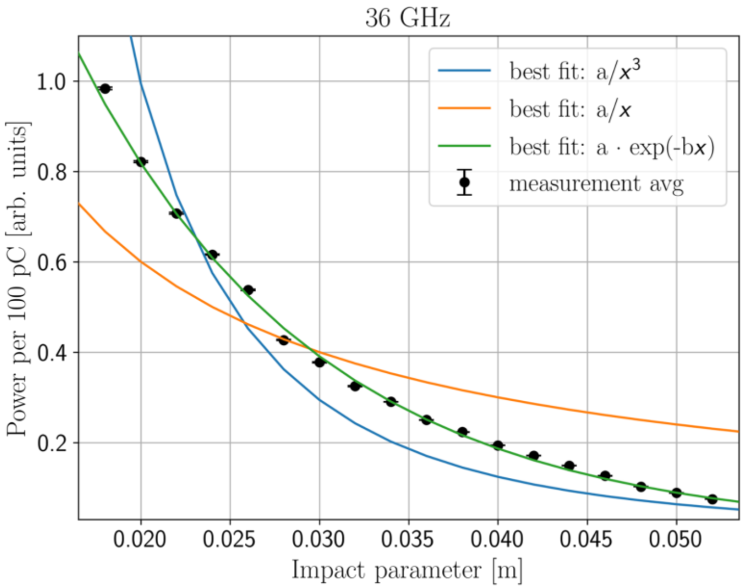


Coherent ChDR light yield

- tests in CLEAR in 2021-2022 (200 MeV e-, 36 GHz). Test in full coherent regime. Impact parameter 20-50 mm
- Results did not support neither Ulrich or PCA models, rather ‘in between‘
- Coherent regime: large yield but large wavelengths: diffraction, angular acceptance.



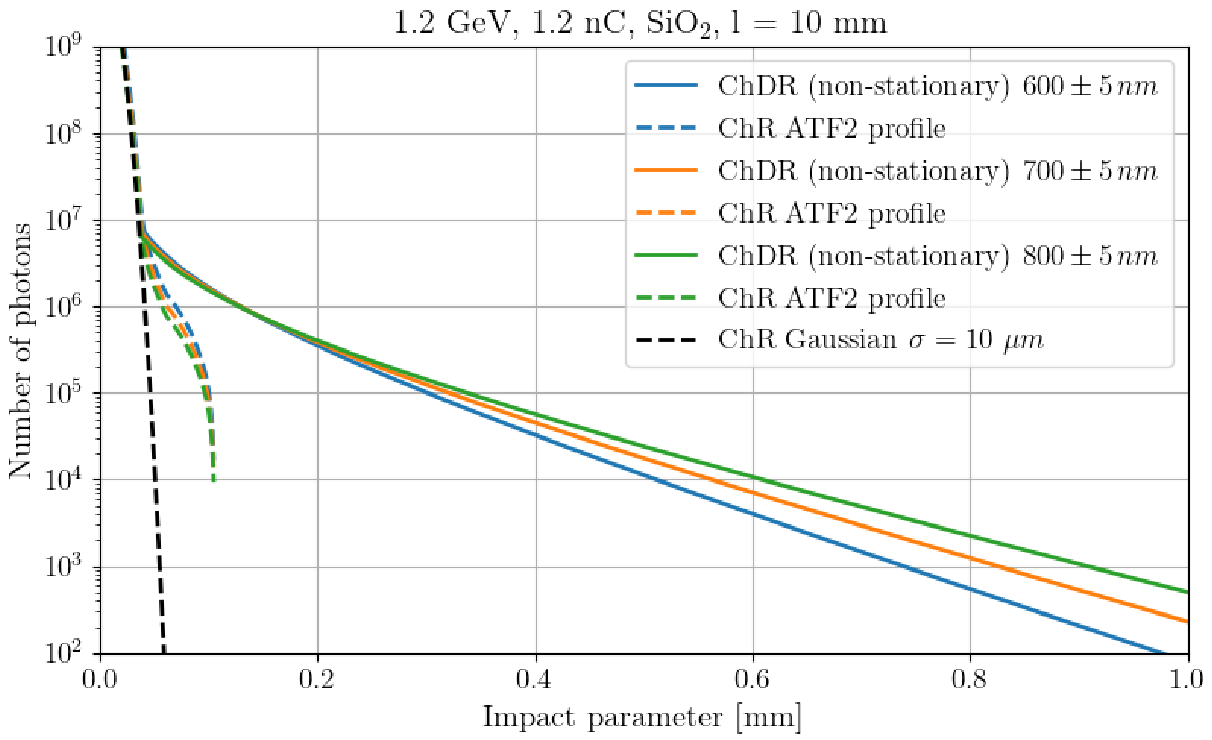




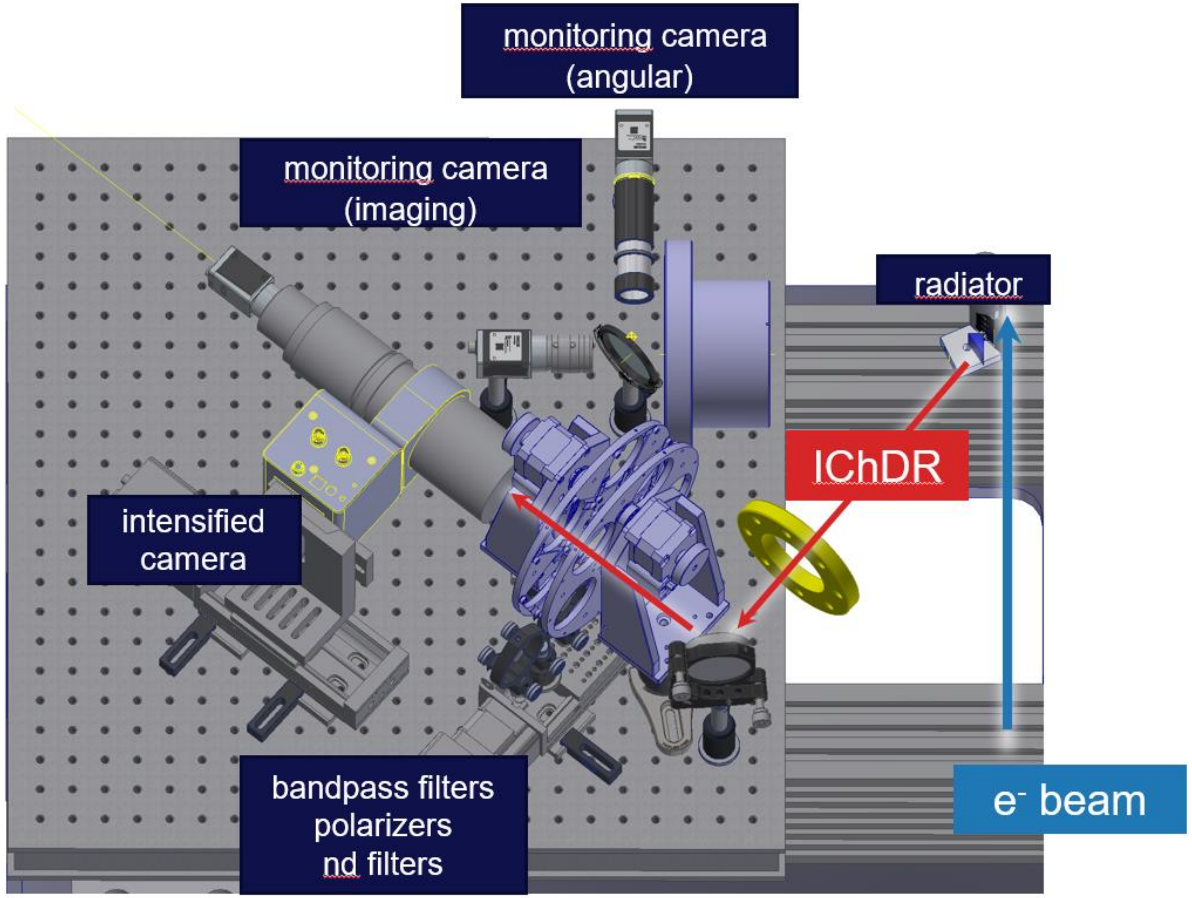
K. Lasocha, IPAC 22

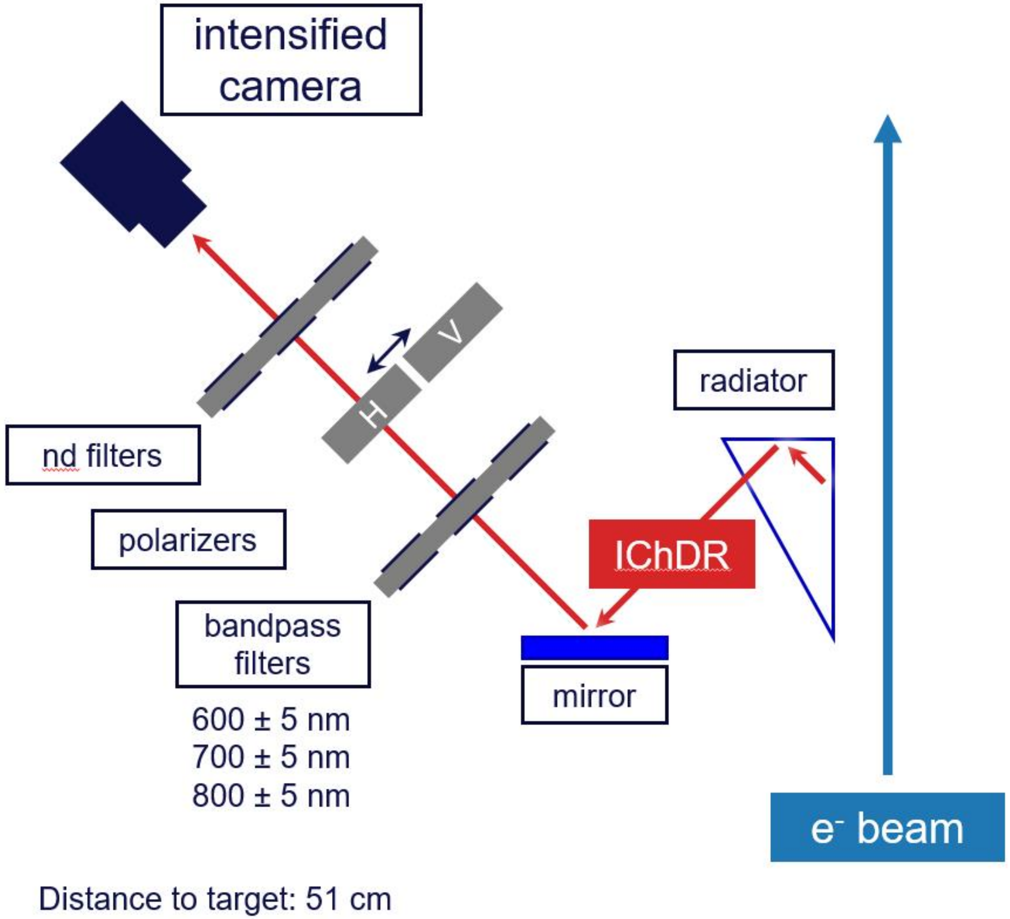
Incoherent optical ChDR yield at ATF2

- **Incoherent visible ChDR offers advantages:**
  - acceptance angle does not depend on impact parameter
  - ‘easy’ absolute detection (visible photons)
  - signal can be used for fast longitudinal profile measurement (streak, single photon TDC,…)
- **…but requires high γ! In clear case, to measure optical ChDR (700 nm) one needs to be as close as 200 um**
- **Need large(r) γ and small beam: ATF2. Accurate halo estimation is mandatory!**

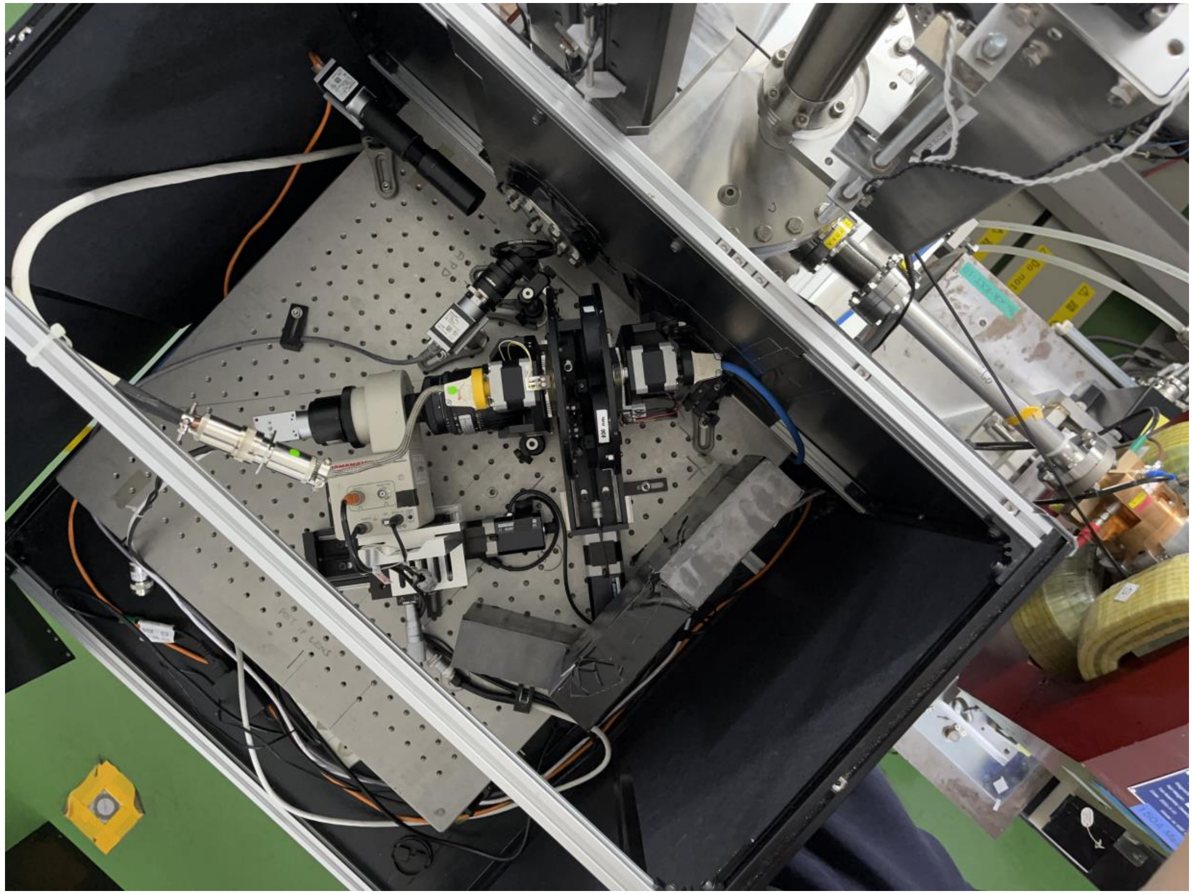


Incoherent ChDR at ATF2 - setup





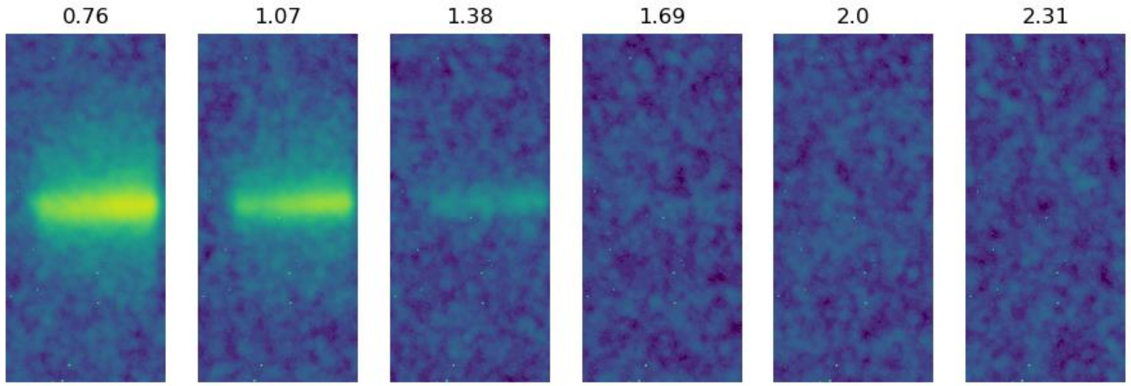
Incoherent ChDR at ATF2 - setup



Summary of June tests

Integrated images

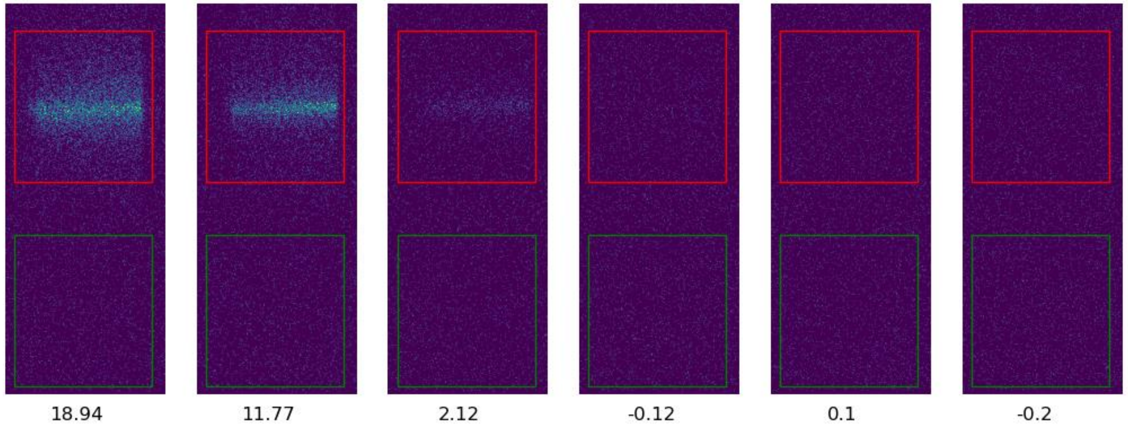
Impact parameter



20 different distances/bandpass filter
500 images per position

Normalized for bunch charge

Photon counting



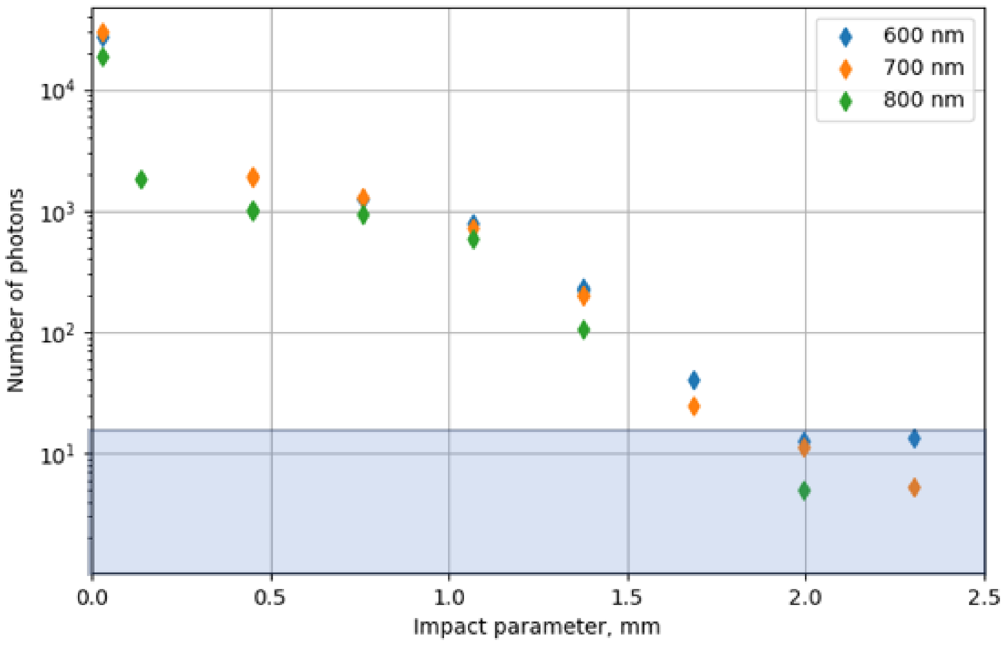
Signal

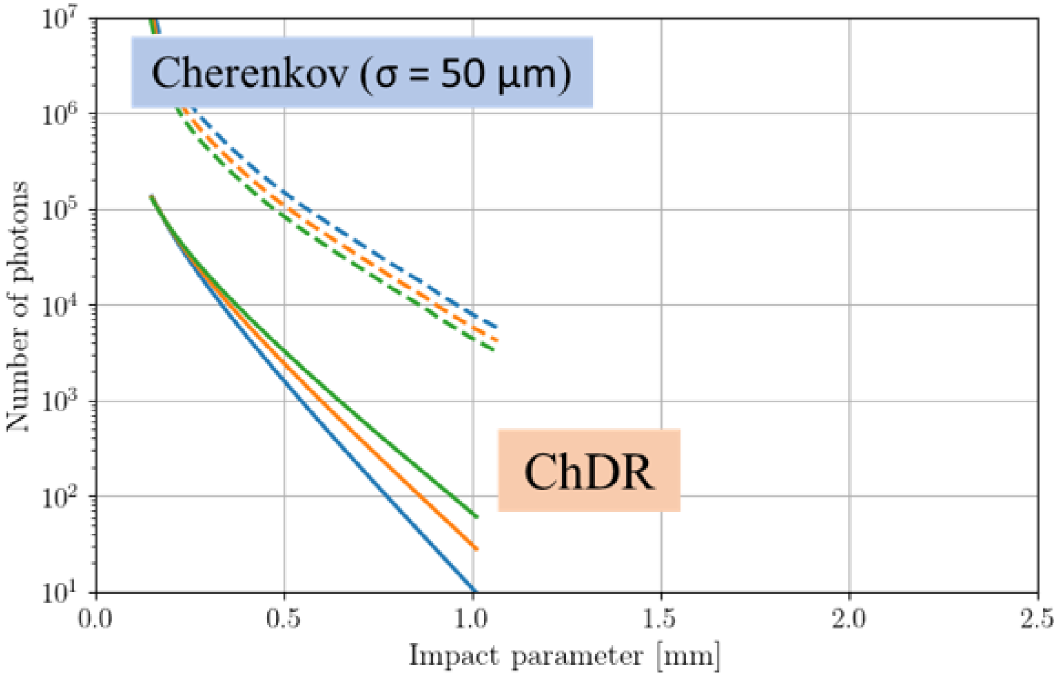
Background

Number of Photons

Summary of June tests

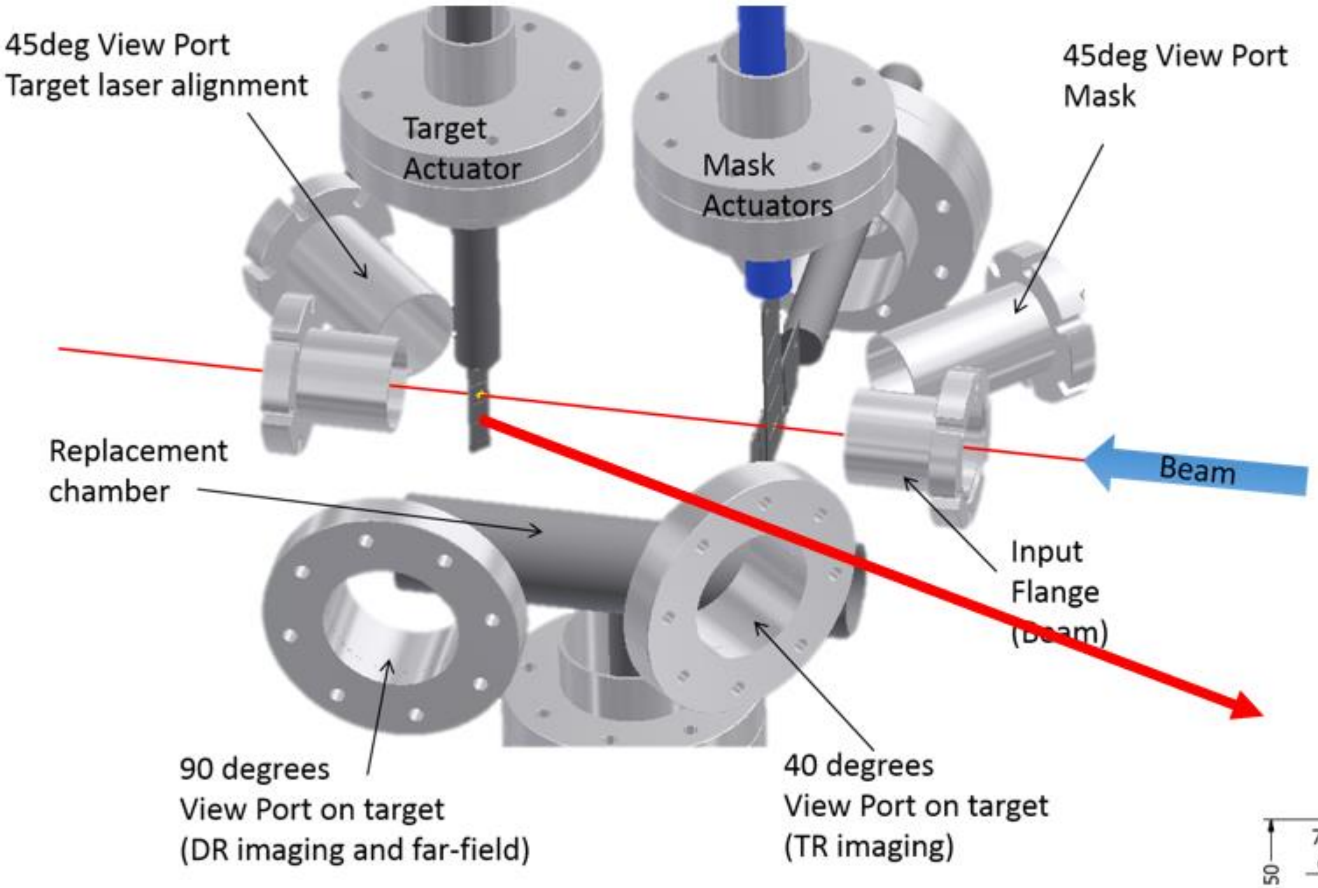
1.3 GeV, 150 pC

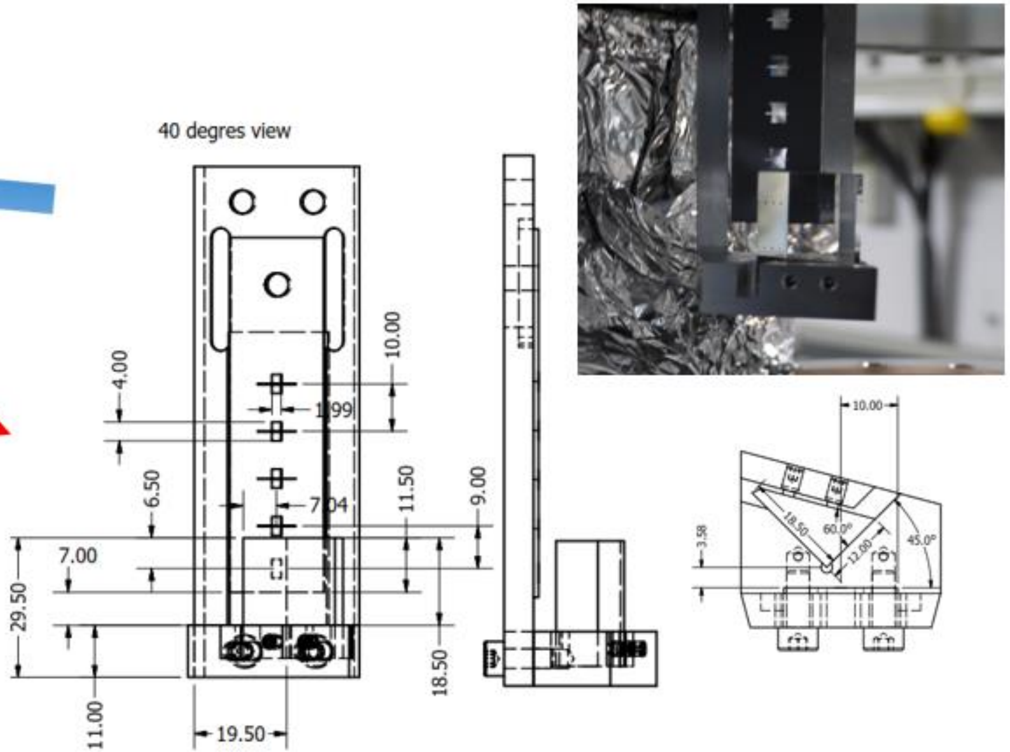




Signal dominated by Cherenkov produced by halo particles crossing the target!

Possible upgrade of ChDR setup





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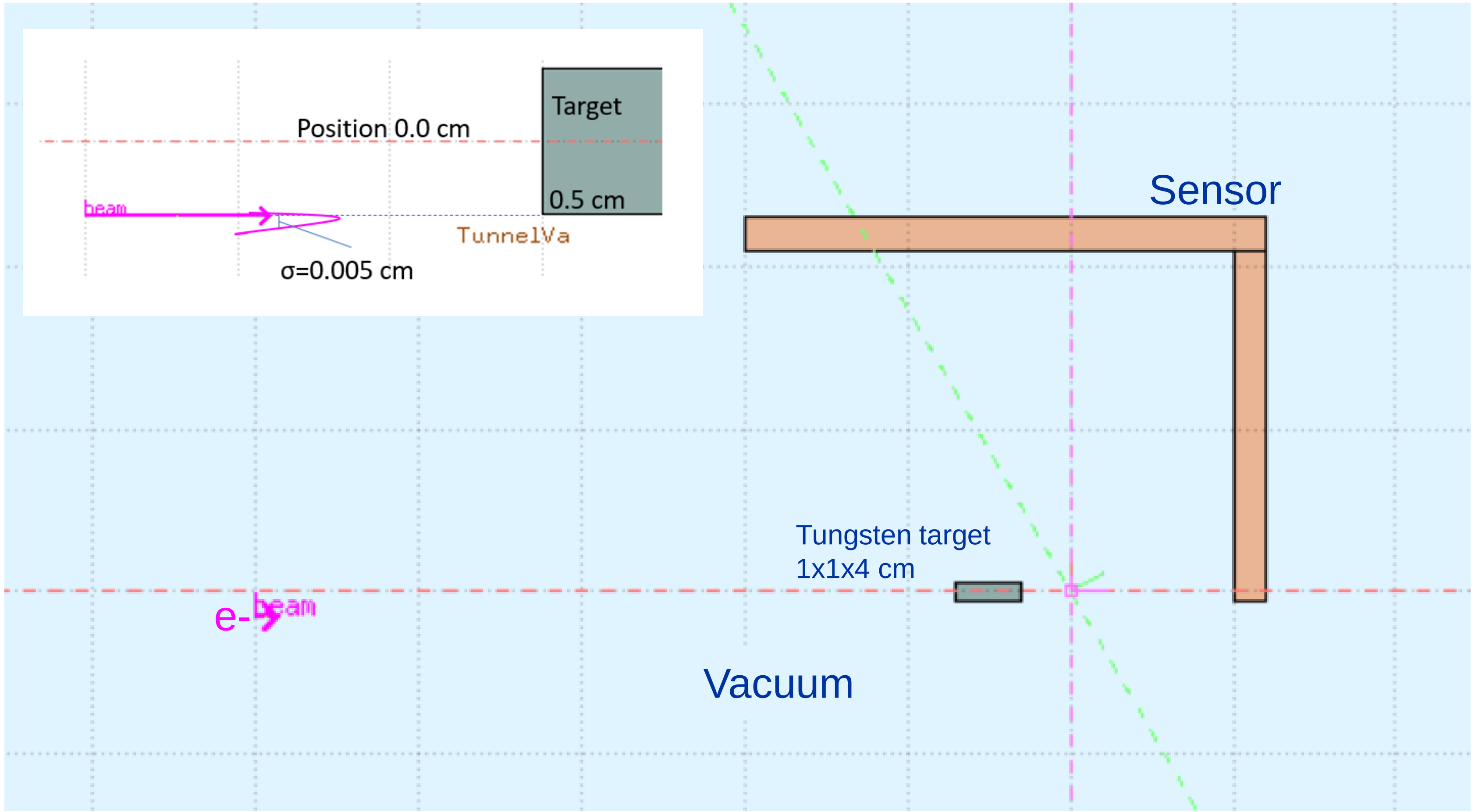
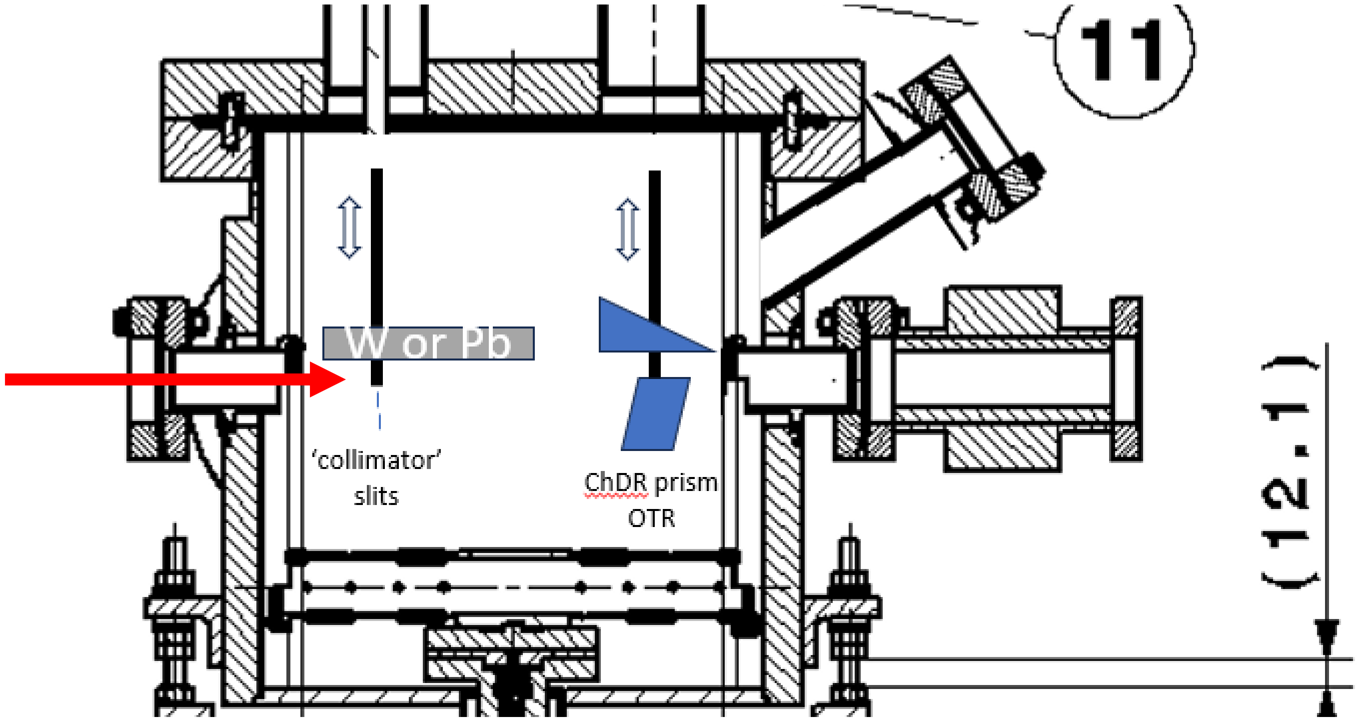


- **FLUKA simulation: effect of 1x1x4 cm W absorber**
- **1.2 Gev, 1,2 nC, 50 um sigma gaussian bunch**
- **Look for charged particles with b>0.685 in a 10 mrad cone co-axial with beam direction**
- **Expected reduction order 10^6**

preliminary estimation performed by S. Benitez

Possible upgrade of ChDR setup



- preserve most of existing design: vertical actuators, support, replacement chamber
- new chamber probably needed for adding 45 deg viewport
- new design should better reject synchrotron radiation (vertical polarisation)

Summary

- Incoherent ChDR can be source for beam diagnostics for future high energy colliders
- Attempts at ATF2 unsuccessful so far, partially due to setup not adapted to ChDR
- (Very) preliminary studies show a possible new setup design that would allow better noise rejection

- New technical student starting in 2024 to measure incoherent ChDR light yield and possibly perform longitudinal profile measurement at ATF2.
- Plan is to perform simulation of new target shielding and of expected halo (vertical plane), then move to design upgrade. Installation / upgrade in 2025.

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