Experimental Verification of Several Theoretical Models for ChDR Description

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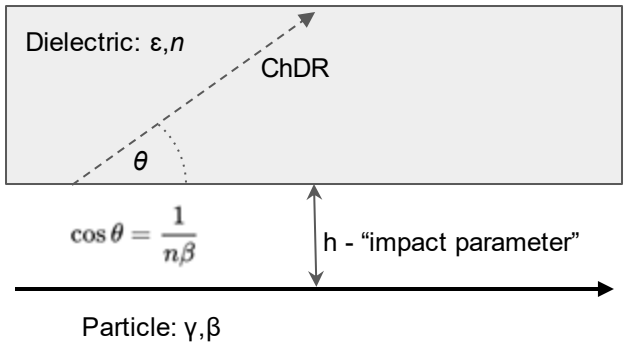
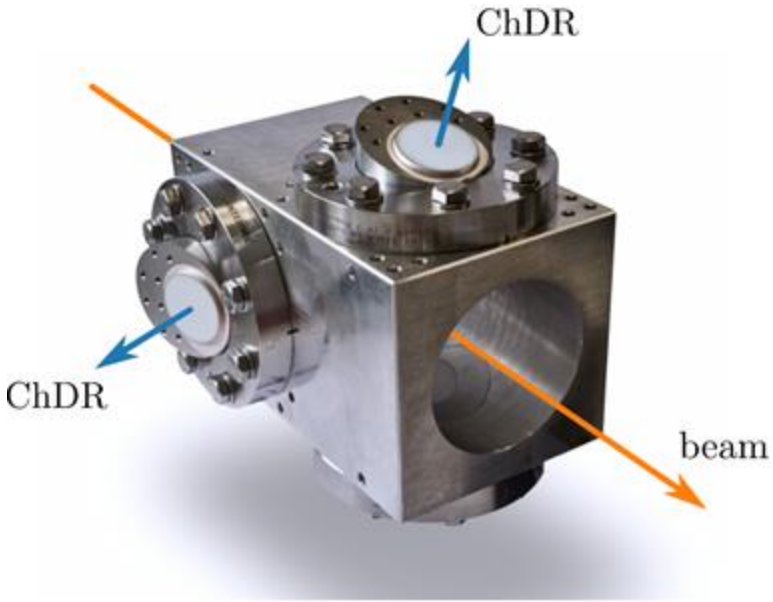
Cherenkov Diffraction Radiation (ChDR)

Emitted when a charged particle passes **<u>in the vicinity of</u>** the dielectric medium at speed greater than phase velocity of the light in this medium.



ChDR for Beam Diagnostics

- **Non-invasive**
- **Very simple design**
- **Photon emission at large angle**



ChDR for Beam Diagnostics

Demonstrations of beam diagnostics with ChDR:

- Transverse bunch profile at ATF-2 in KEK (Proceedings of IPAC2019, WEPGW077)
- Bunch length at CLEAR at CERN (Phys. Rev. Accel. Beams 23, 022802, 2020)
- Beam position at CLEAR at CERN (Proceedings of IBIC2021, MOPP17)

Other facilities that confirmed feasibility of observation of ChDR:

- CESR at Cornell University, USA (Phys. Rev. Lett. 121, 054802, 2018; Phys. Rev. Accel. Beams 23, 042803, 2020)
- Diamond Light Source, UK (Proceedings of IBIC2019, WEPP037)
- CLARA at Daresbury Laboratory, UK (Proceedings of IBIC2019, TUCO02)
- t-ACTS at Tahoku University, Japan (Proceedings of IPAC2019, WEPGW031)
- Microtron at Tomsk Polytechnic University, Russian Federation (Scientific Reports 10, 20961, 2020)

Under investigation application of ChDR as a tool for beam diagnostics in:

- ★ Advanced WAKEfield Experiment (This conference, MOPOPT053, MOPOPT042)
- ★ Future Circular electron-positron Collider (FCC-ee) (A. Schloegelhofer, FCC Week 2022)

Theoretical models of ChDR emission

Stationary ChDR:
Bolotovski, Ulrich, Olsen

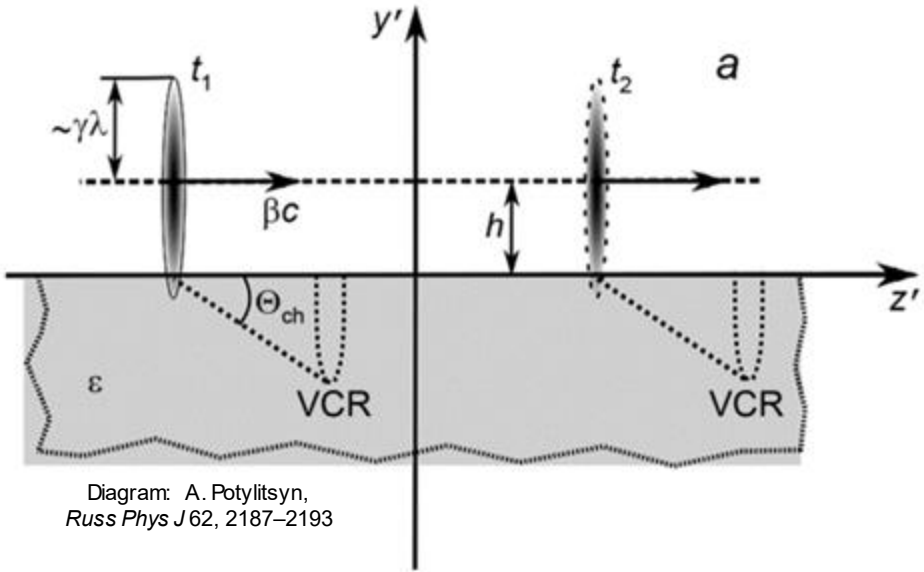
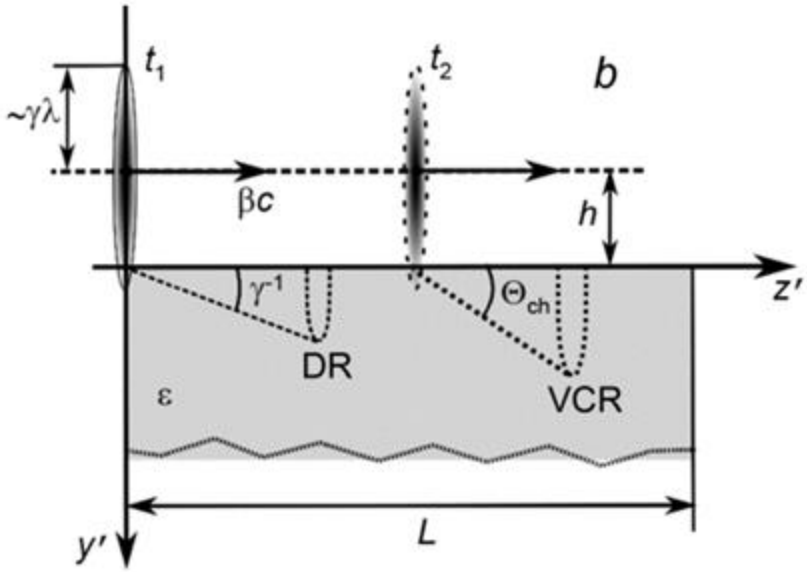


Diagram: A. Potylitsyn,
Russ Phys J 62, 2187–2193

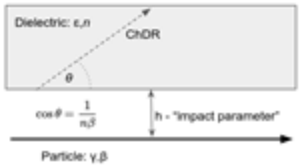
Non-stationary ChDR:
Polarization Current Approach (PCA)

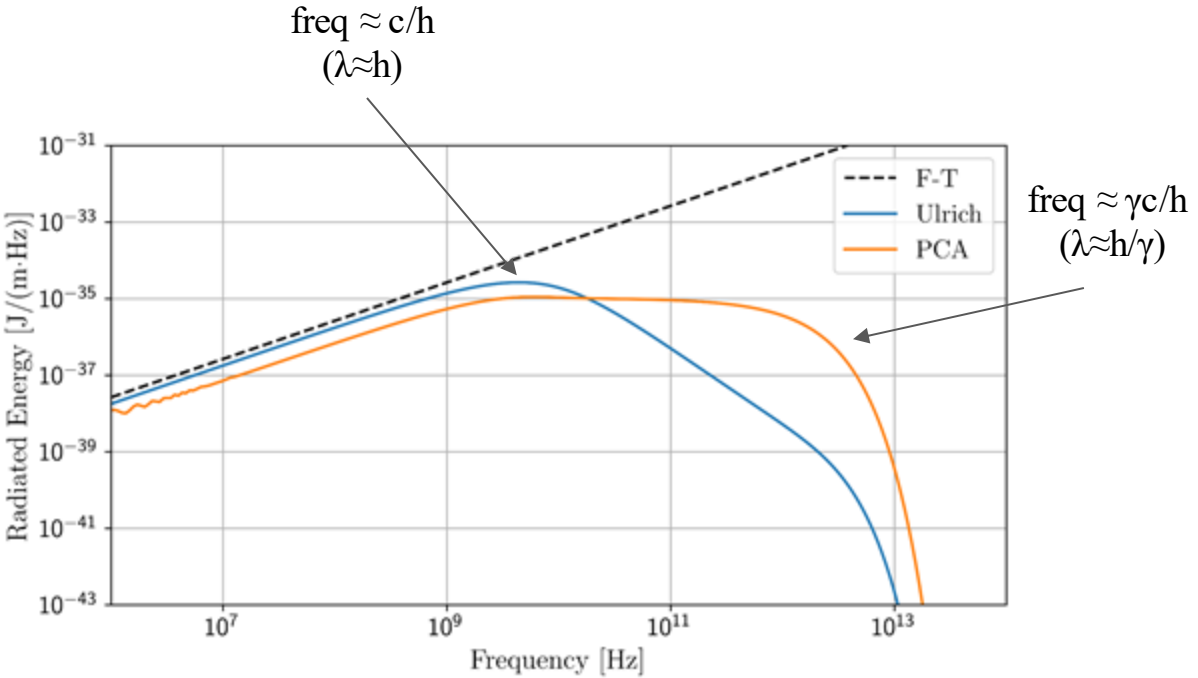


1 B.M. Bolotovskii, Sov. Phys. Usp. 4 781 (1962).
2 Ulrich, Z. Physik 194, 180–192 (1966).
3. H. A. Olsen and H. Kolbenstvedt, Phys. Rev. A, vol. 21, Jun 1980.
4. Karlovets, D.V., Potylitsyn, Jetp Lett. 90, 326 (2009).

Spectral distribution of ChDR (clear)

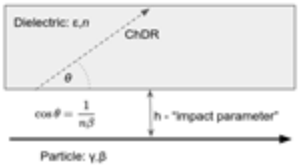
E = 200 MeV
γ ≈ 392
h = 2 cm
eps = 2.1

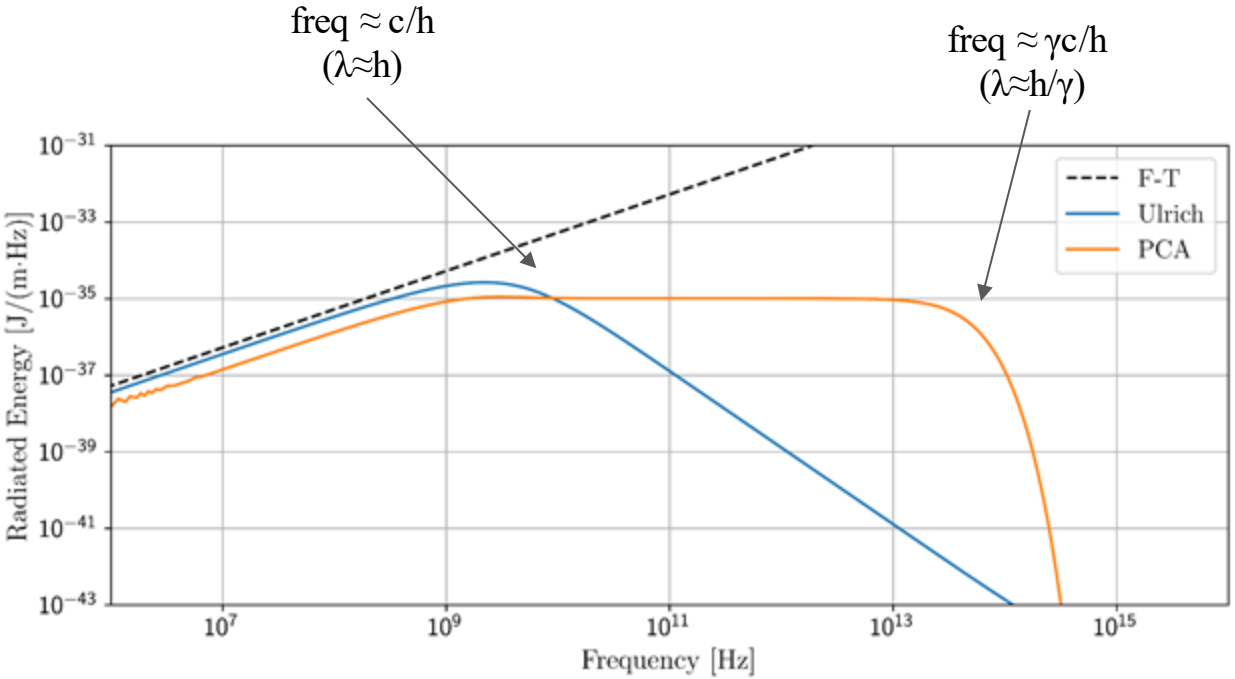




Spectral distribution of ChDR ( )

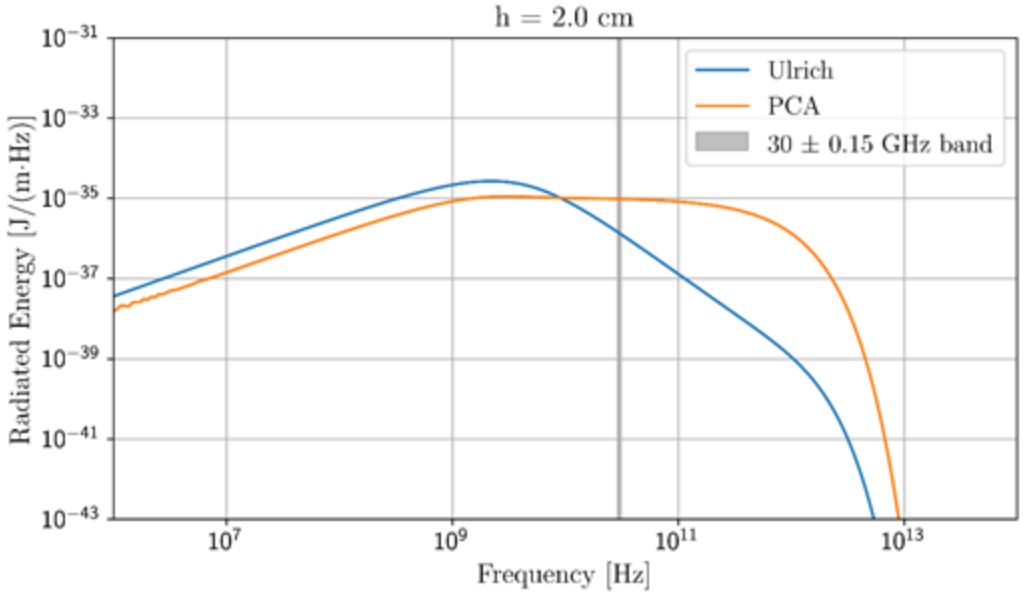
E > 45 GeV
γ > 88000
h = 2 cm
eps = 2.1





27 nC bunch emits 10^3-10^6 photons in visible range per cm… according to PCA

Proposed experimental verification at clear

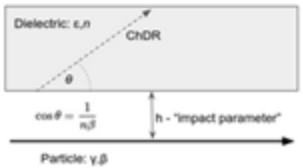


h = 2 cm

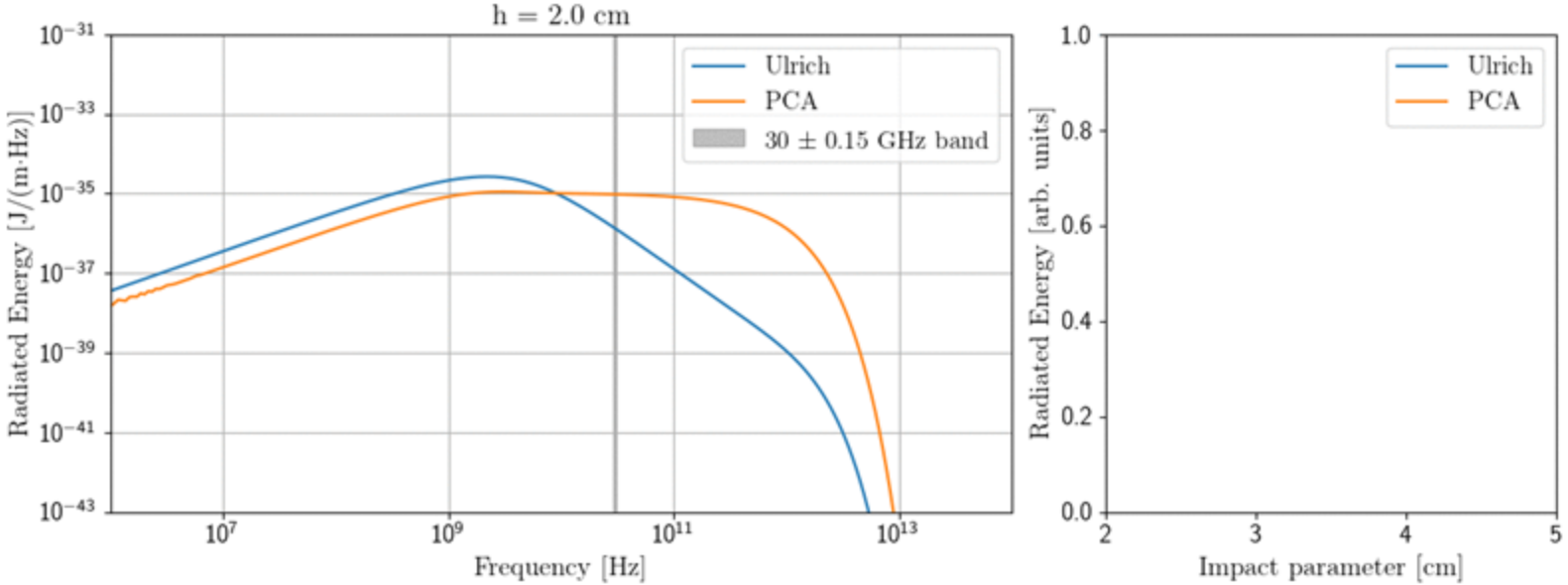
γ ≈ 392

eps = 2.1

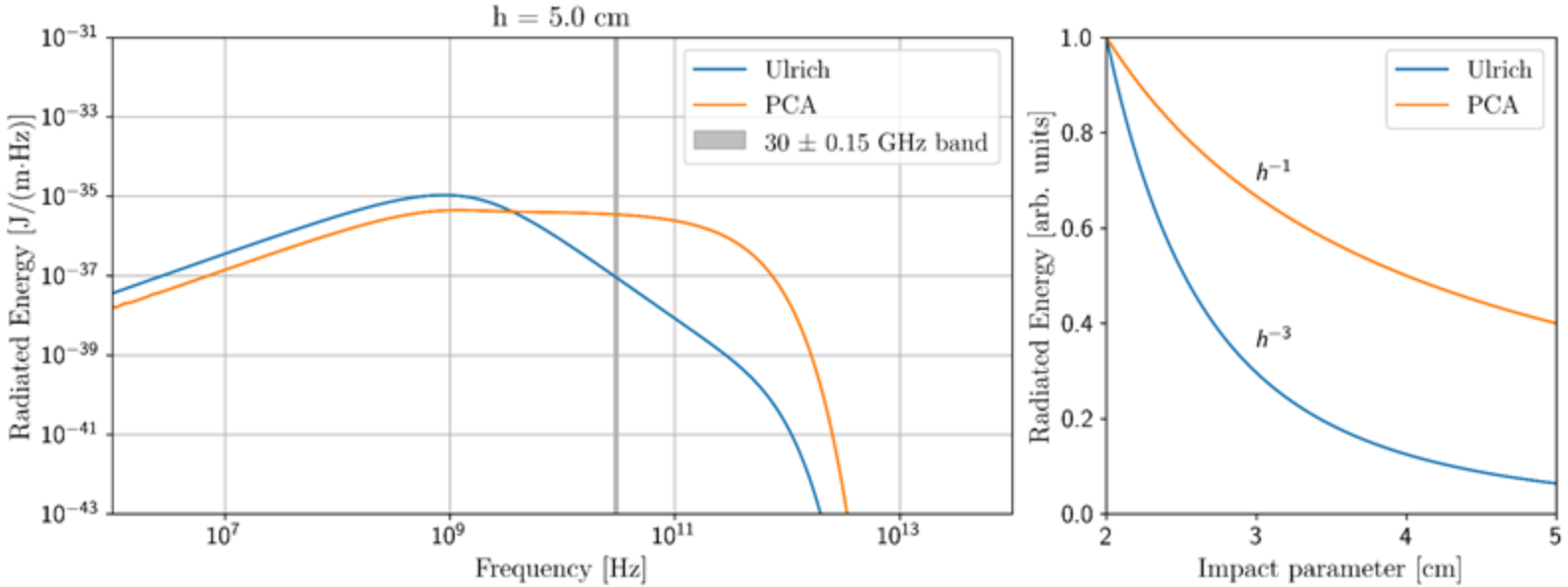
freq = 36 GHz



Proposed experimental verification at clear



Proposed experimental verification at clear



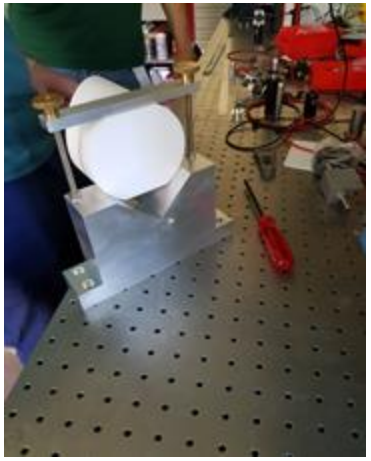
Observation of ChDR power as a function of impact parameter verifies investigated models.

Radiator

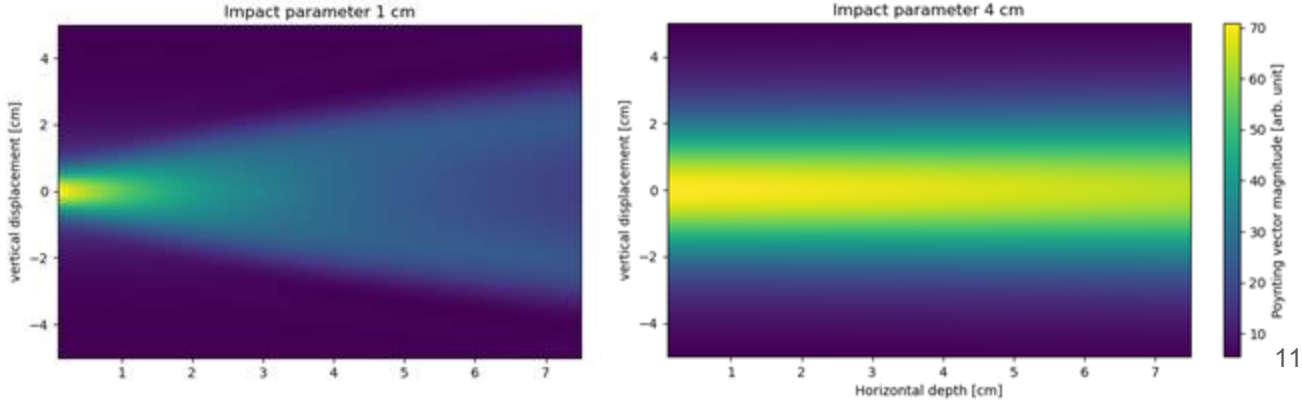
- PTFE rod

$$\theta_{ChDR} = \arccos \frac{1}{n\beta} \approx 45^\circ$$

- 10 cm diameter
- 10 cm length
- cut at 45 degree



Radiator size chosen based on stationary ChDR simulation



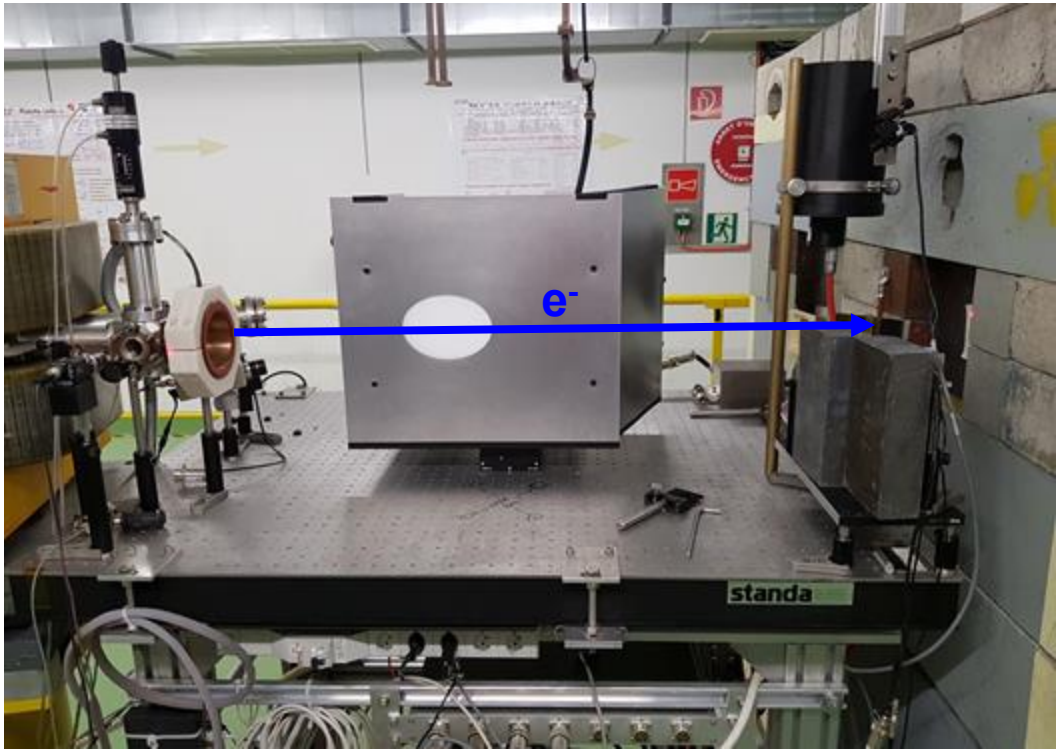
Experimental setup

- Aluminium shielding of radiator and measurement system,

- In-air Cherenkov radiation contributes only for impact parameters less than 2 cm, as:

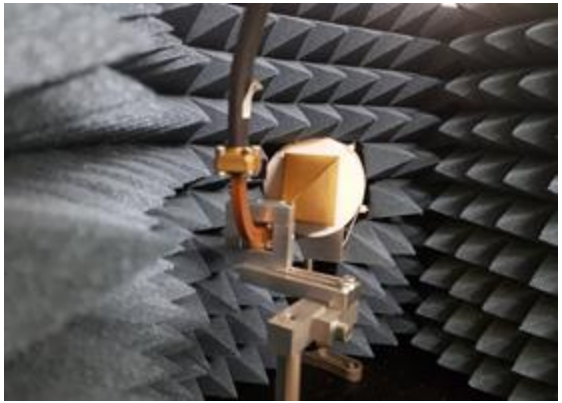
$$\theta_{ChR_{air}} \approx 1.4^{\circ} ,$$

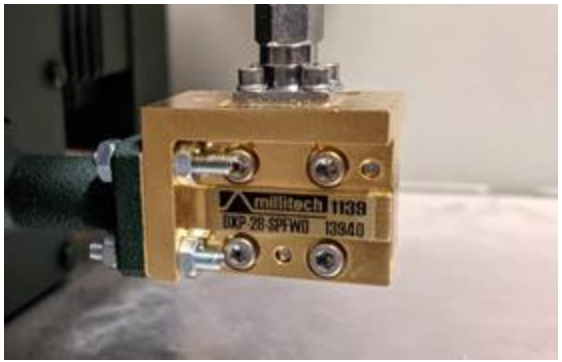
- Setup placed on a movable horizontal motor with 0.7-11 cm range.

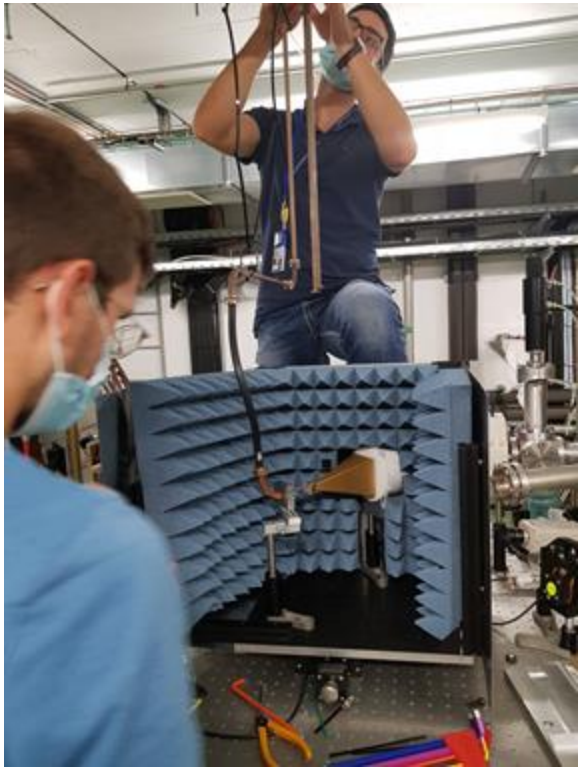


Acquisition system

- Horn antenna with 36 (30) GHz band-pass filter,
- W28 waveguide network, attenuation independent on the setup position
- RF Diode working in linear regime, input power constant due to the attenuator,
- Signal digitized with a 4 GHz scope.







Data collection

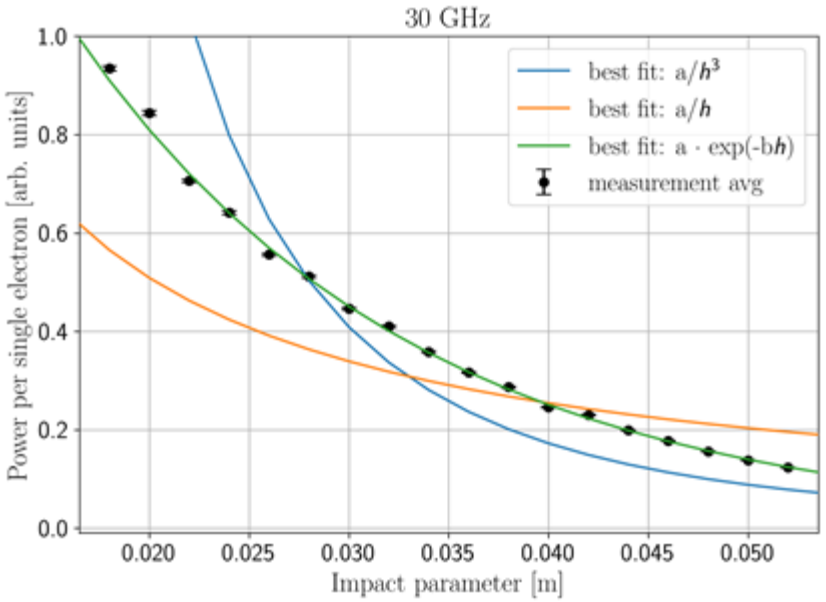
September 2021 session:

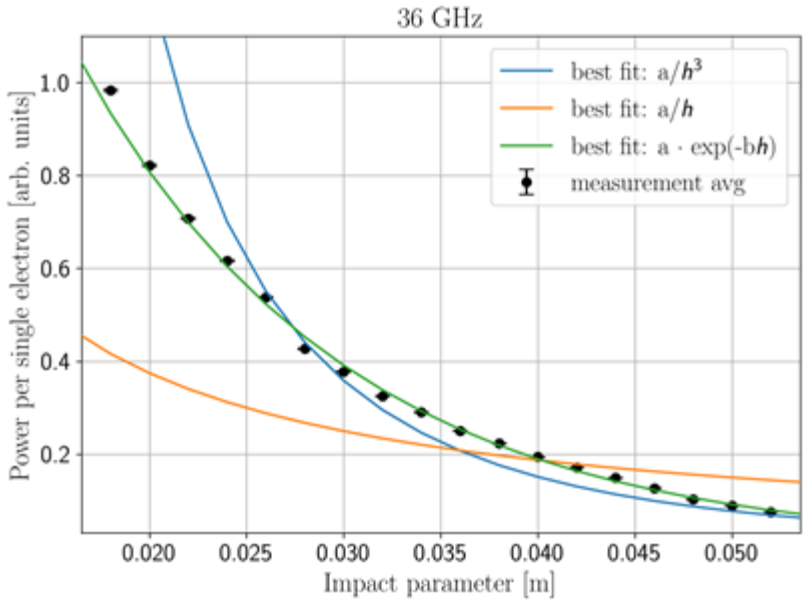
- Energy 220 MeV,
- 30 GHz (300 MHz BW) and 36 GHz (1 GHz BW) band-pass filter,
- i.p. between 0.8 and 11 cm (step of 2 mm) ,
- 200 RF diode voltage acquisitions at each i.p., bunch charge controlled.

November 2021 session:

- Energies 100, 150, 200 MeV,
- Only 36 GHz band-pass filter,
- i.p. between 1 and 8 cm (step of 4 mm) ,
- 200 RF diode voltage acquisitions at each i.p, bunch charge controlled, x2,
- Bunch size & position variations included, bunch length monitored.

Impact parameter scan at 220 MeV



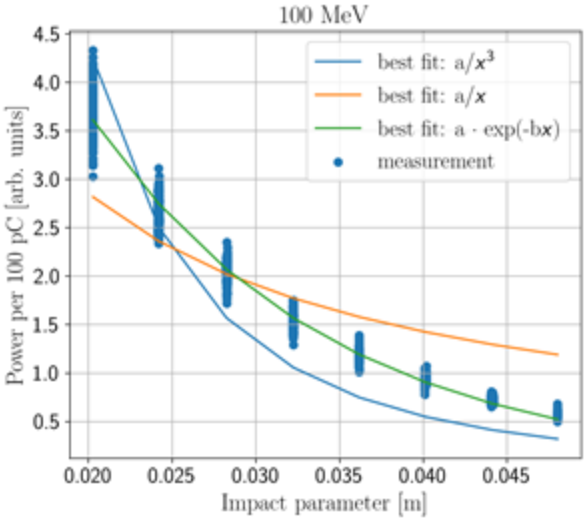


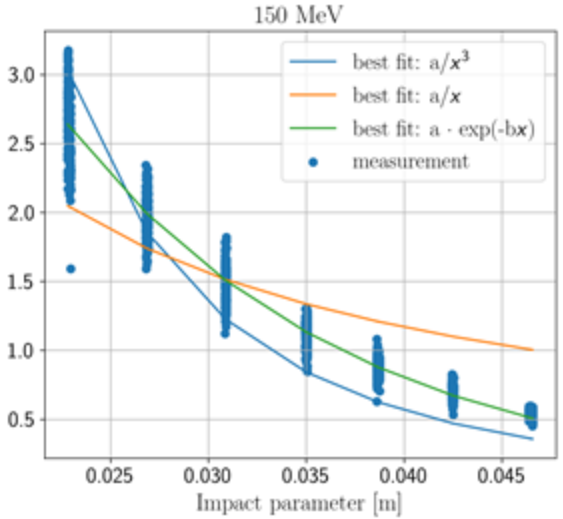
Least squares fitted b ≈ 58.28

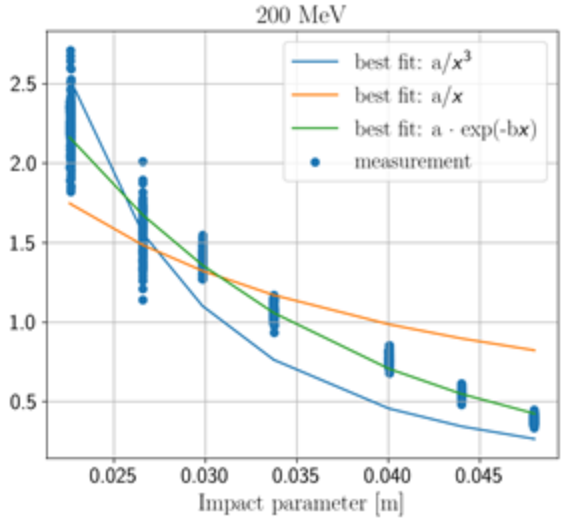
Least squares fitted b ≈ 72.52

72.52 : 58.28 ≈ 36 GHz : 30 GHz

Impact parameter scans at 100-200 MeV, 36 GHz

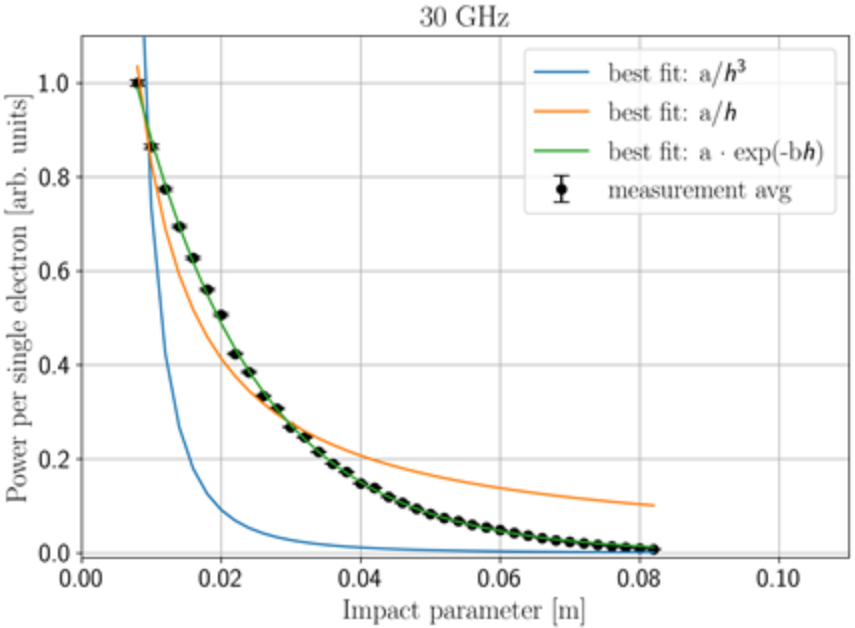


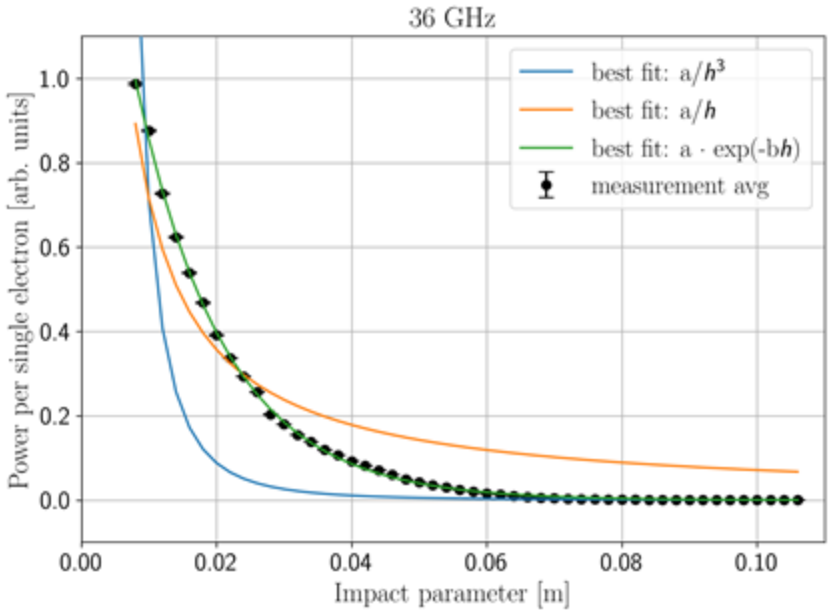




Exponential b∈ [64.1, 72.6], with no energy dependence observed.

Impact parameter scan over full motor range (220 MeV)





Exponential shape is preserved over the full motor range.

Conclusions & Future plans

- In intermediate frequency range, ChDR power is given as an exponential function of the impact parameter, not predicted by any of the investigated models,
- Exponential *b* coefficient seem to be dependent on the frequency, but not on the beam energy.

Next steps:

- Theoretical and experimental investigations on effect of radiator edges and size on the emitted radiation,
- Series of tests using electrons and positrons with energies from 10 to 300 GeV at the CERN SPS fixed target facility to study the ChDR in the visible range.

Thank you for your attention!