pfRICH - R&D for future upgrades

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(for pfRICH group)

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Outline

- Ongoing Efforts for HRPPD Sensors [sort-term]
  - Aging
  - B-Field
  - Many more..
- Future ideas for pfRICH as a whole [long-term]
  - Aerogel
  - HRPPD
  - Simulation
  - Consortium Formation

HRPPD Aging Studies

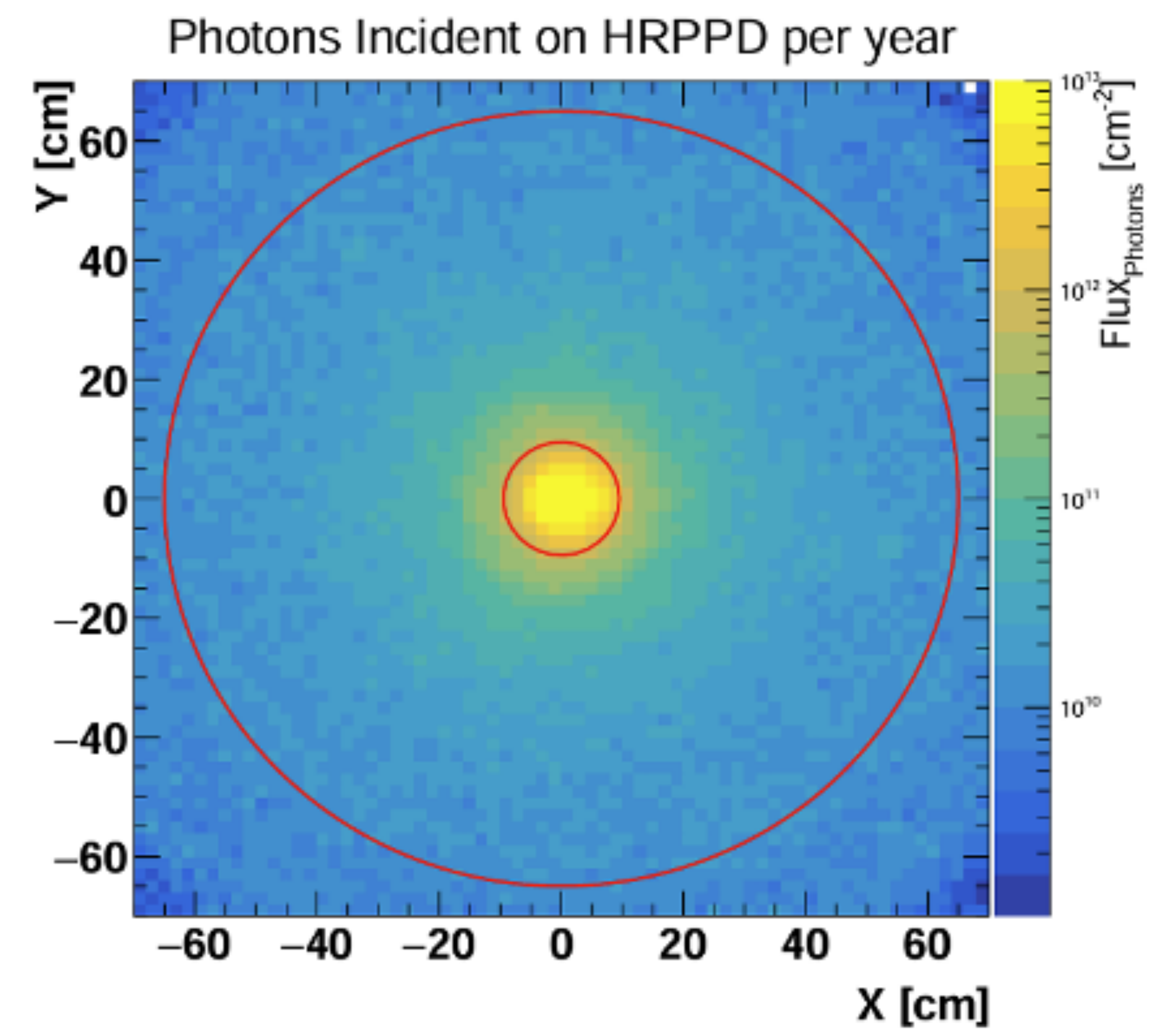
- The beam induced charged particle background impacts the pfRICH mainly via excess photons produced in the aerogel and fused silica windows of the HRPPD photo sensors.
- A fraction of the incoming photons are converted to photo-electrons (PE) by the photocathode according to its quantum efficiency.
- The amplification of PEs due to a secondary electron emission in the MCPs desorpts ions off the micro-channel walls.
- These ions drift towards the photocathode, and can react with or even sputter the photocathode material which leads to degradation of its quantum efficiency.
- HRPPD gain can also be affected due to a degradation of the secondary emission layer.

over ten years or ePIC running

~10^{13} *detected* Cherenkov photons per cm^2

~0.11 C/cm^2 accumulated charge @ gain ~10^5

Expected photon fluence in ePIC experiment

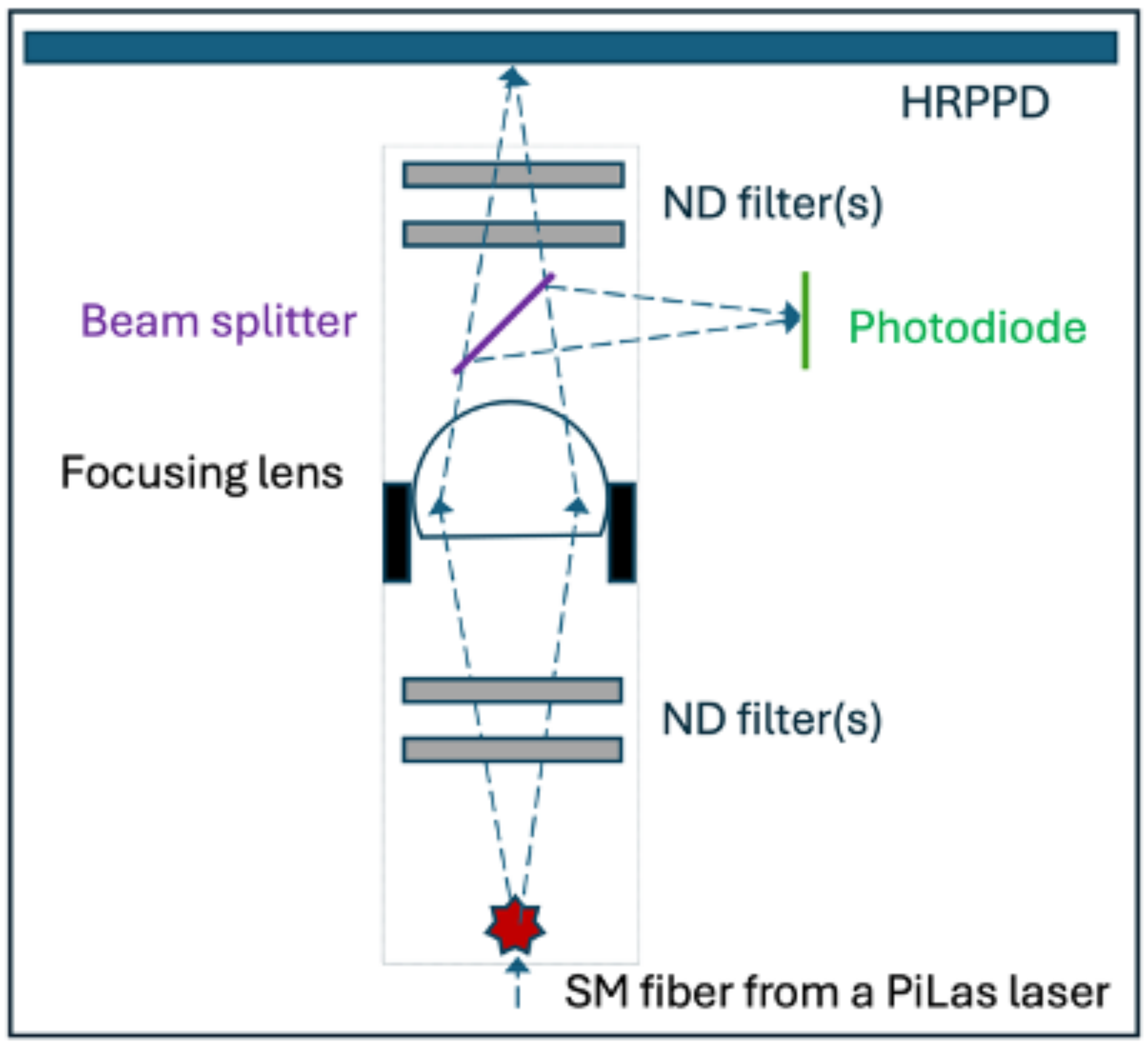


A detected Cherenkov photon flux incident on HRPPD photocathodes at pfRICH location in ePIC over a year of running

HRPPD Aging Studies

Primary Goal:

- Prove that EIC HRPPDs will work under conditions typical for their installation place in ePIC
- Use a laser photon fluence as a direct measure of a damaging factor.
- With pulsed laser measure a Photon Detection Efficiency (PDE) degradation to evaluate the photocathode directly.
  - ➡PDE drop in a single photon mode as a function of integrated photon flux.
- Gain degradation is of a little concern at the expected photon fluence, however the evaluation for this performance parameter will be provided as well.



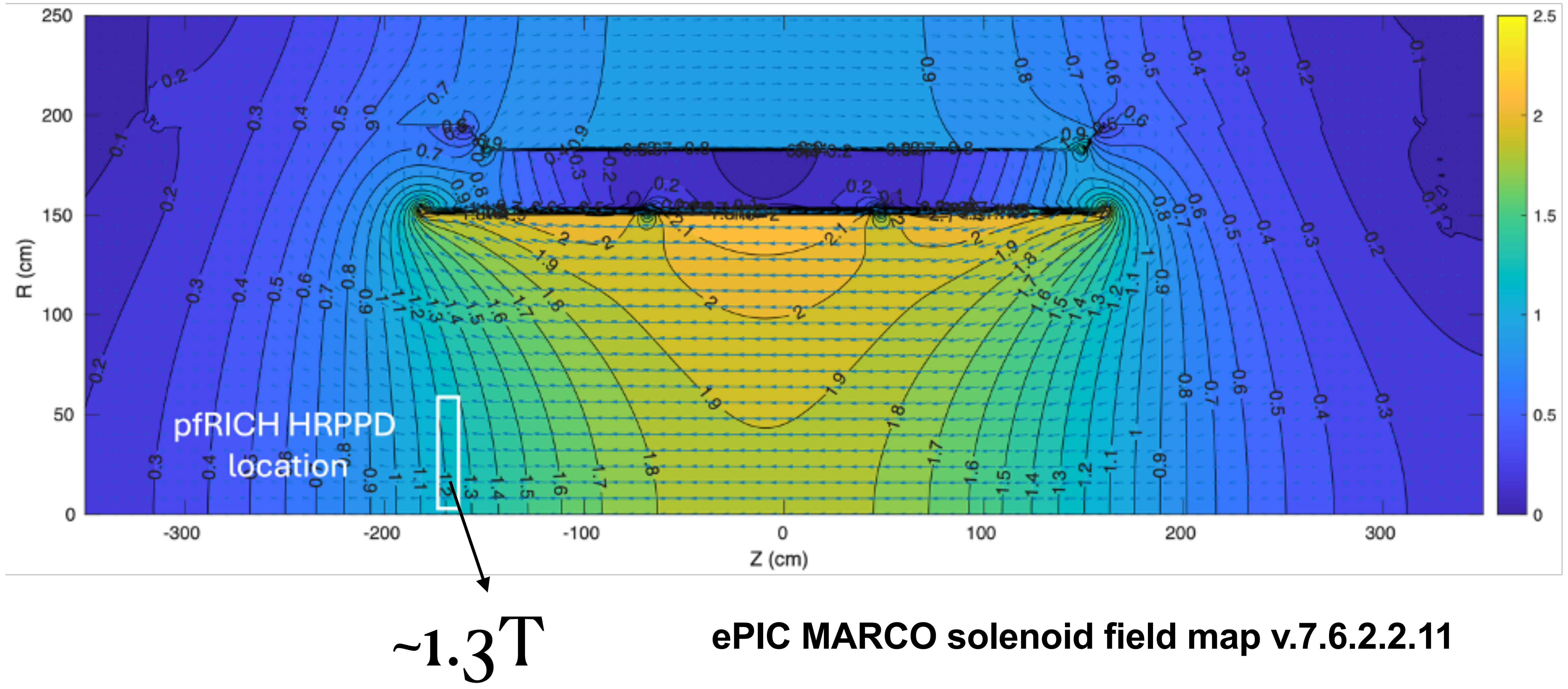
Optical head setup

HRPPD B-Field Studies

- The main goal is *to prove that EIC HRPPDs will properly work in a B-field configuration of the 2T ePIC MARCO solenoid magnet at their installation place in ePIC.*

- *Study if the* HRPPD gain degradation in a strong magnetic field can be mitigated by ramping up MCP bias voltage,

- Check the single photon timing resolution or deterioration of any other essential performance characteristic



ePIC MARCO solenoid field map v.7.6.2.2.11

Maximum inclination of 12 deg. for the photosensors installed close to the outer shell of the vessel

HRPPD B-Field Studies

- Plan is to test it unto up to +/- 15 degrees range of field line to window normal in both horizontal projections, with a step of 3-5 degrees.

A warm 18D72 type dipole at BNL Superconducting Magnet Division, with a maximum field strength of 2.2 T

Measurement program

- Pulse height distribution (summed up over 3x3 pads)
- Gaussian width of the timing distribution core as defined by a leading edge fit
- Width of the spatial distribution in X&Y (using amplitudes across 3x3 pads)
- Position of the XY-centroid as determined by a weighted mean across 3x3 pads
- Dark Count Rate (DCR)
- Relative photon detection efficiency (count of events where HRPPD had a visible pulse, at a constant laser repetition rate), as well as event count above some reasonable threshold, defined as a fraction of observed MPV
- After pulsing rate

Future Ideas: HRPPDs

Potential improvements to the photosensors could be realized with future R&D in collaboration with Incom

Reducing the pore size of the MCPs from 10 to 6 micrometers
- Reduce timing resolution below 20 ps
- Increase TOF PID capabilities to higher momentum
- Maintain performance in high magnetic fields

Wavelength shift of photocathode material to higher wavelength
- Increase QE peak towards green

Window material and thickness improvements: Explore alternative window materials such as Sapphire with and without anti-reflective surface and the use a thinner window material
- Decreases the material budget and overall longevity of the sensors

Increase the HRPPD active area by modifying the side wall design and adjusting MCP manufacturing process to cut corners and increase size
- Up to 80% geometric efficiency

Highly pixelated anode: decrease the anode pitch by a factor of 2
- Improves Cherenkov angle resolution

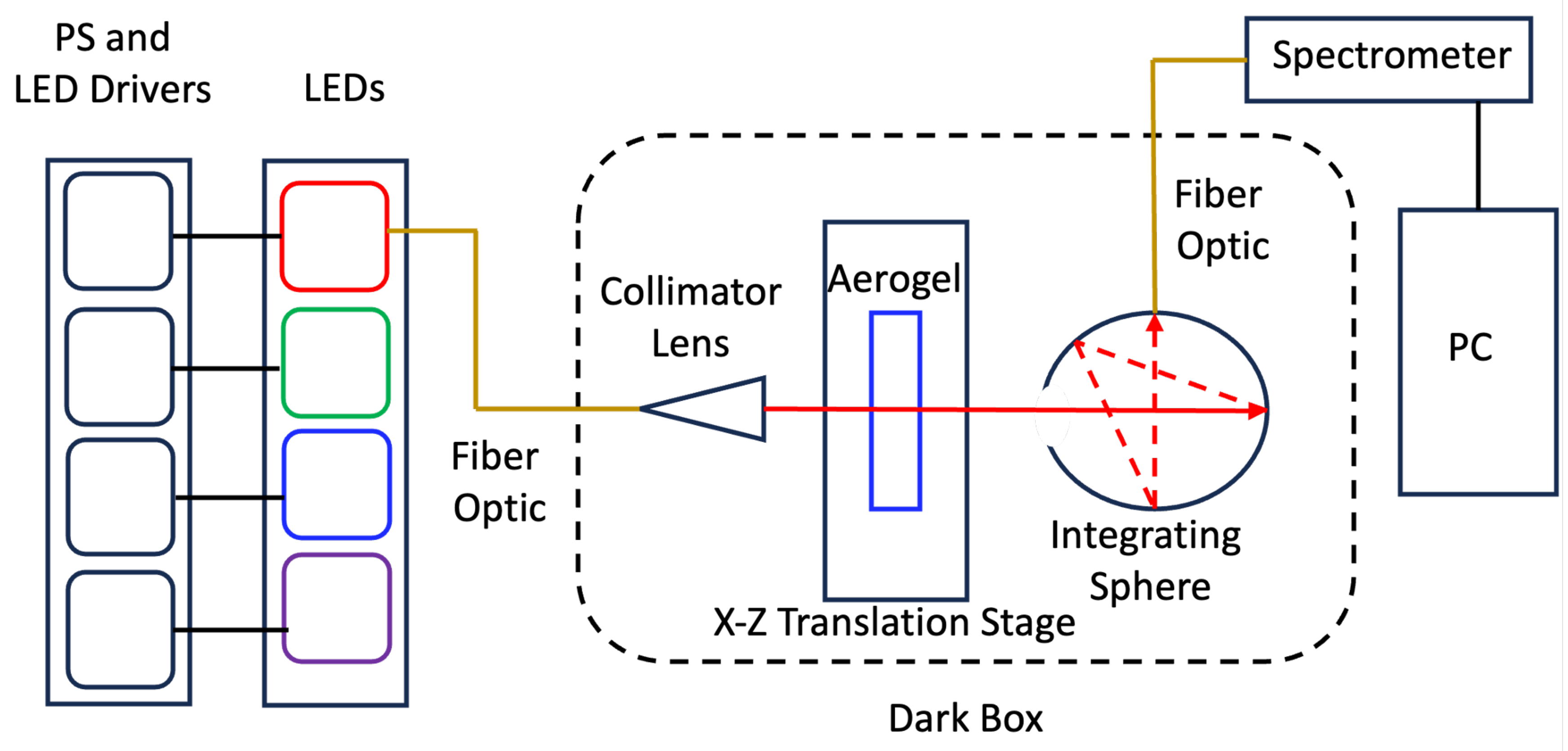
Improve hadron PID in e-going direction, extend to higher momentum reach in p-going direction by factor of two, and improve durability in high magnetic field

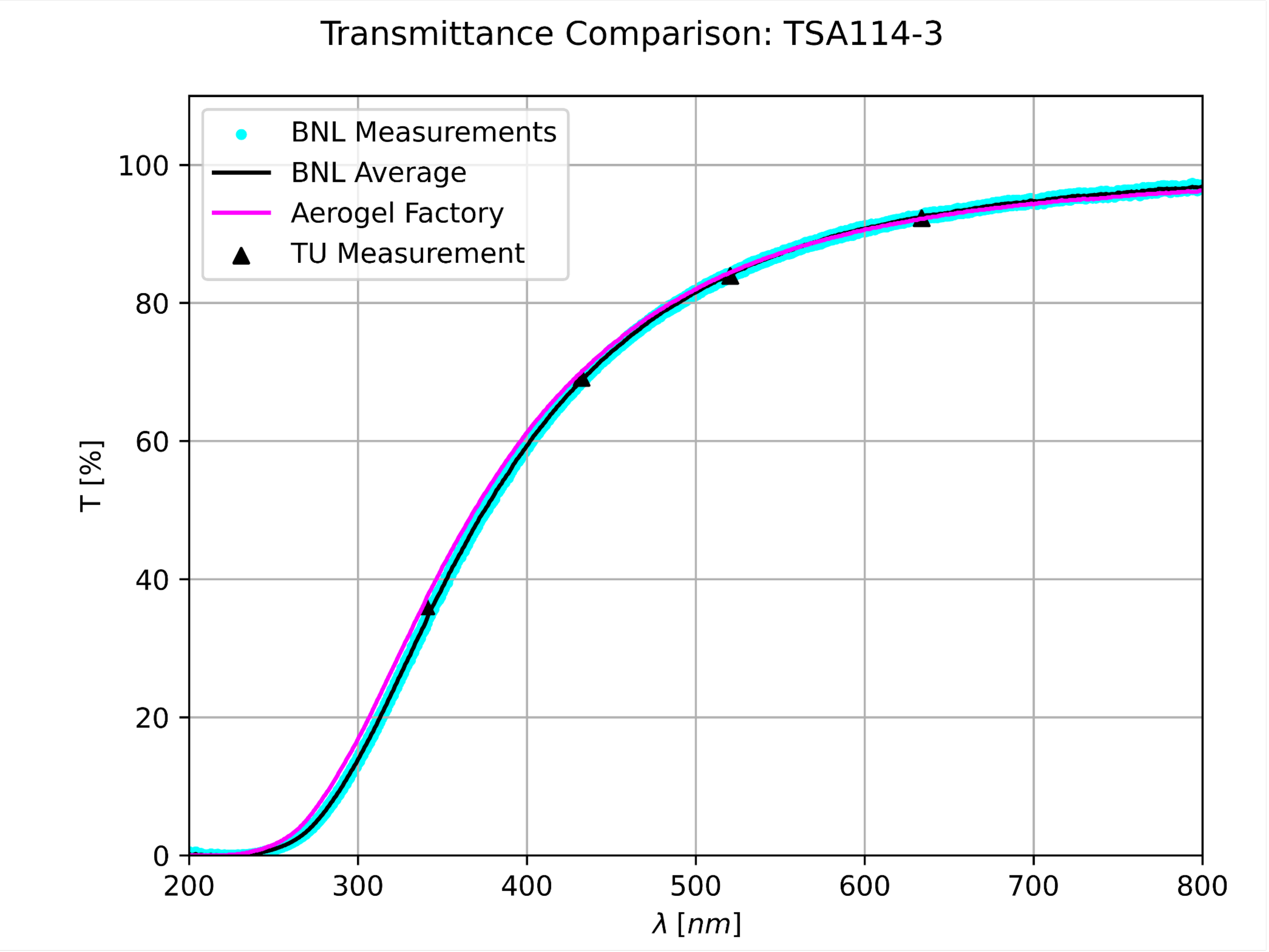
Future Ideas: Aerogel

Potential improvements to the areogel could be realized with future R&D with Temple

close collaboration with Chiba University (a.k.a Aerogel Factory)
Currently produced at Aerogel factory and tested at Temple

Ongoing R&D studies to reduce the index of refraction of the aerogel





Increase the momentum reach with the aerogel material, overall reducing the material budget

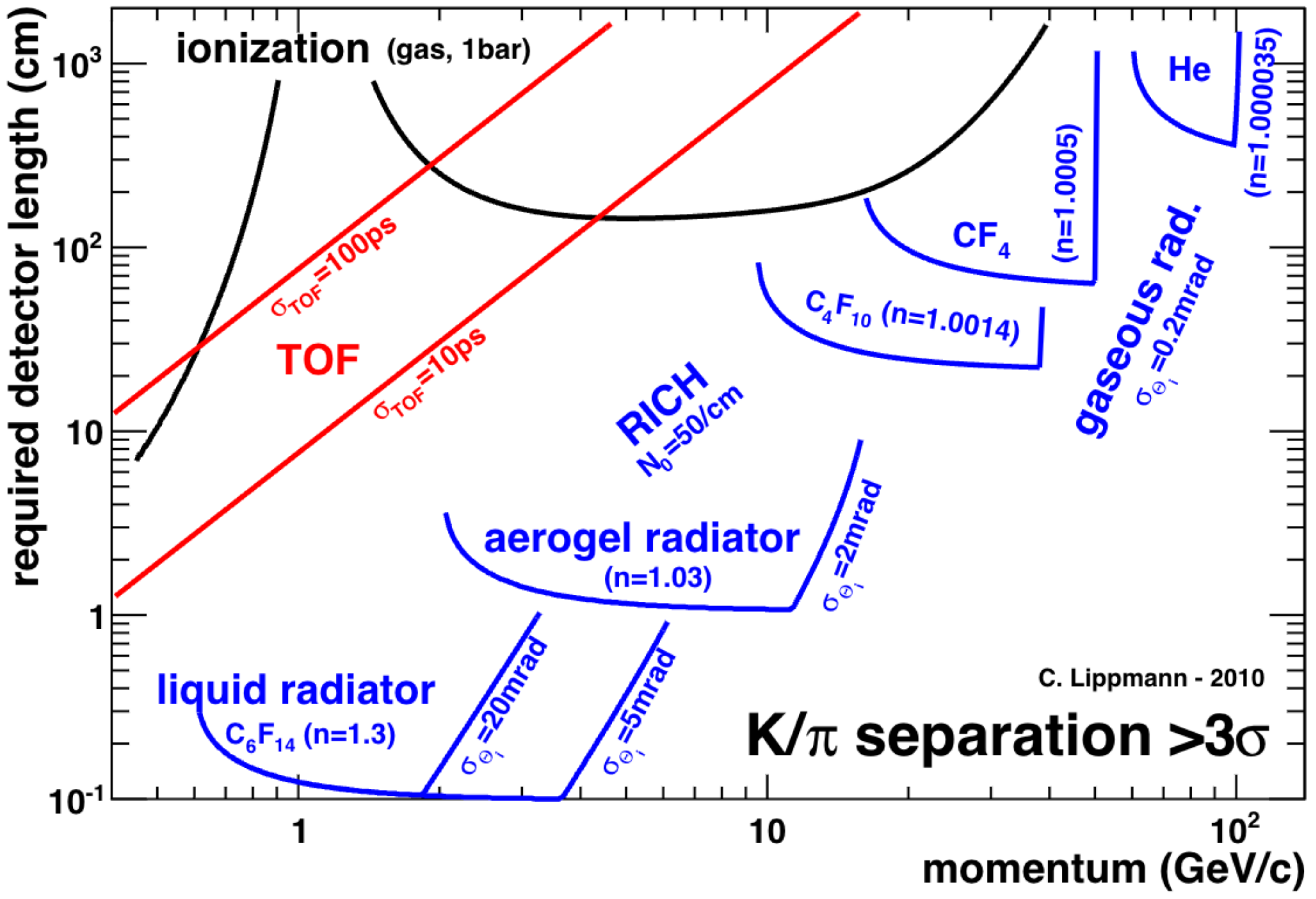
Simulations for improvements to pfRICH

Perform simulation studies to determine the most impactful improvements to the sensors and aerogel to focus the R&D efforts

Based on the existing standalone ePIC pfRICH GEANT simulation suite with existing Inverse Ray Tray (IRT) reconstruction

Ability to vary refractive index and transmission of aerogel, sapphire window specs, QE(λ) dependency, pixel size, pitch size, and magnetic field

Explore improvements to the timing resolution, single photon resolution, hadron PID separation and momentum reach



Preliminary studies show a Cherenkov photon resolution below 1 mrad, meaning ~ 3σ π/K separation at 15 GeV/c

Also the idea is to develop a self sufficient set-up at Yale to have various studies.

Plan is to work more towards forming a consortium mainly focused on Future improvements

Thank You