

pfRICH prototype participation in the hpDIRC Cosmic Ray Telescope installation at Stony Brook

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ePIC pfRICH DSC Meeting, 02/19/2025

Objectives

- No test beam availability at Fermilab in 2025
 - Perhaps in 2026 as well (?)
- We face the same situation as in January 2024: no real urgency for a beam test
 - Just because CD2/3 timelines shifted by one year (and CD-2 is about 60% readiness)
- Going to CERN with dRICH *now* does not really see a support by the EIC Project
 - And it is clear we will not have a luxury of going to test beams every year anyway
- How about a cosmic ray test stand *somewhere* in the meantime?
 - Need a reasonable tracker, t_0 reference and means to select high momentum muons
- This is pretty much what CRT at Stony Brook is

Objectives

- Bring workforce, expertise and equipment to help cover hpDIRC own needs
 - DAQ, high resolution timing reference (HRPPD), APV25 electronics, ..?
- Use this opportunity to test HRPPDs with hpDIRC prototype (!)
 - May be essential for their adoption as a baseline photosensor solution (instead of Photek)
 - Substantially improves chances of getting ~\$50k from EIC Project for HGCROC3 readout
- hpDIRC CRT team (Greg, Jaydeep, Joe, Nathan) see the idea quite positively

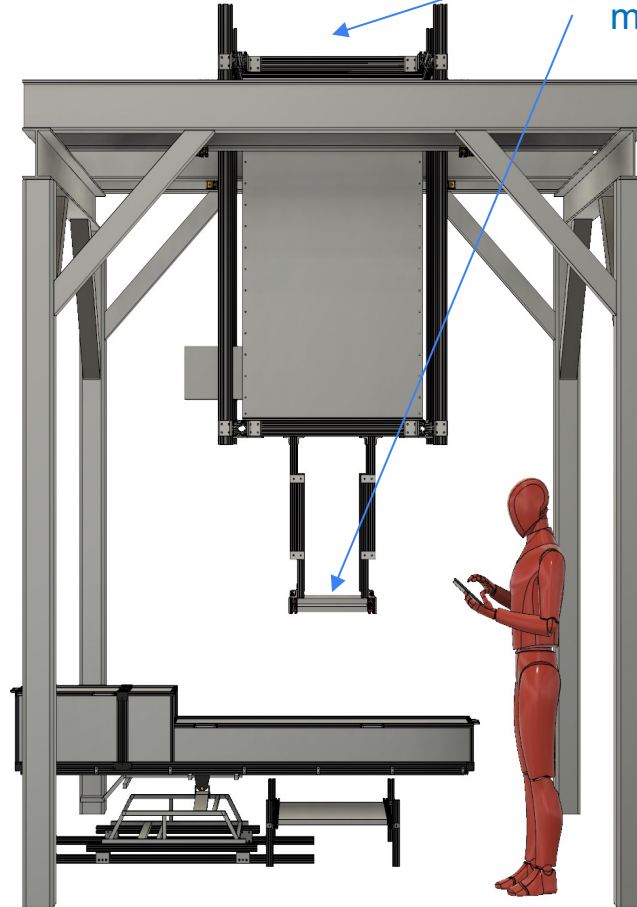
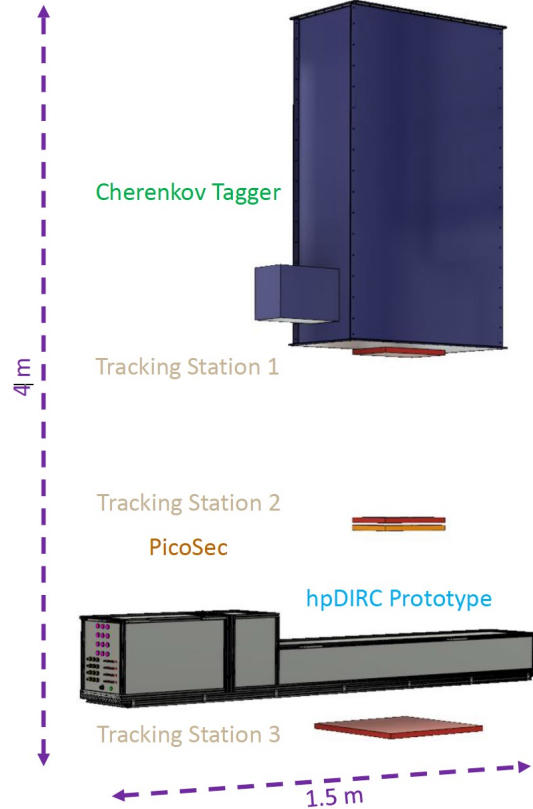
*CRT installation
at Stony Brook*

Configuration

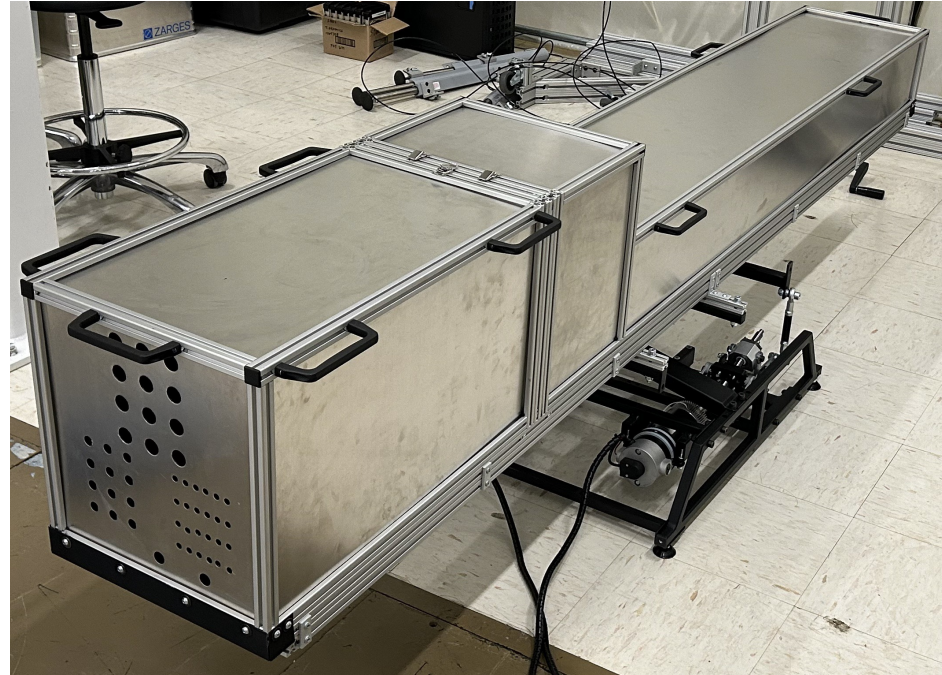
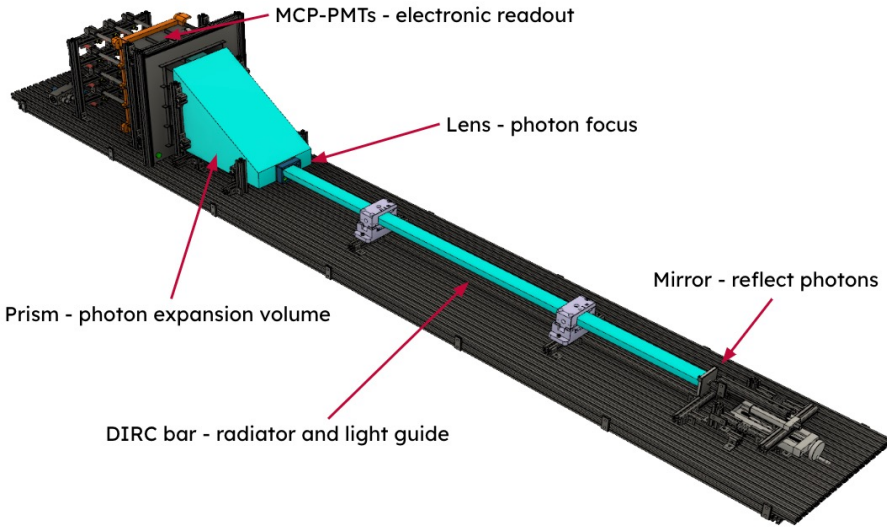
- A solid 4m high alu profile / 8020 based tower
- hpDIRC prototype dark box with a motion control
- μ RWell tracker with VMM3a readout
 - Should provide ~ 0.5 mrad or better angular resolution
- PICOSEC detector with SAMPIC readout
 - Can provide as good as ~ 40 ps timing reference
- Cherenkov threshold counter
 - To cut away muons below ~ 3.5 GeV/c
- Multi-anode Planacons with a TRB readout
 - To detect photons reaching the rear side of the hpDIRC expansion volume prism
- A synchronized multi-host DAQ to configure and read all this stuff out

Configuration

CRT setup CAD schematic

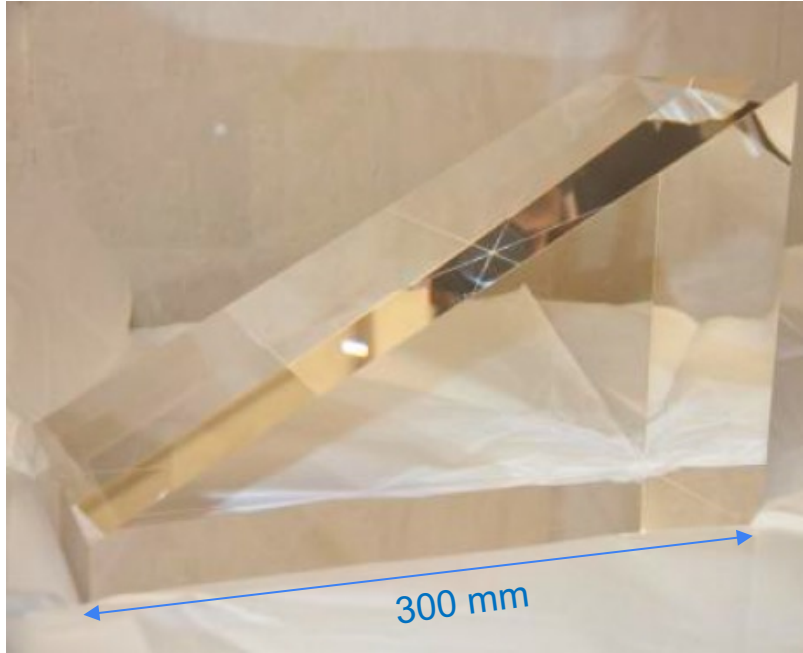


hpDIRC prototype in a dark box



- Dark box is complete, but the actual set of bars & a prism are still at JLab

Fused silica prism and MCP-PMT matrix



side view of a prism



MCP-PMT matrix

- This prism is a miniature version of a one to be used in a final hpDIRC design
- Rear side 175mm x 244mm (a 2x2 or perhaps even 1x2 HRPPD matrix would suffice)

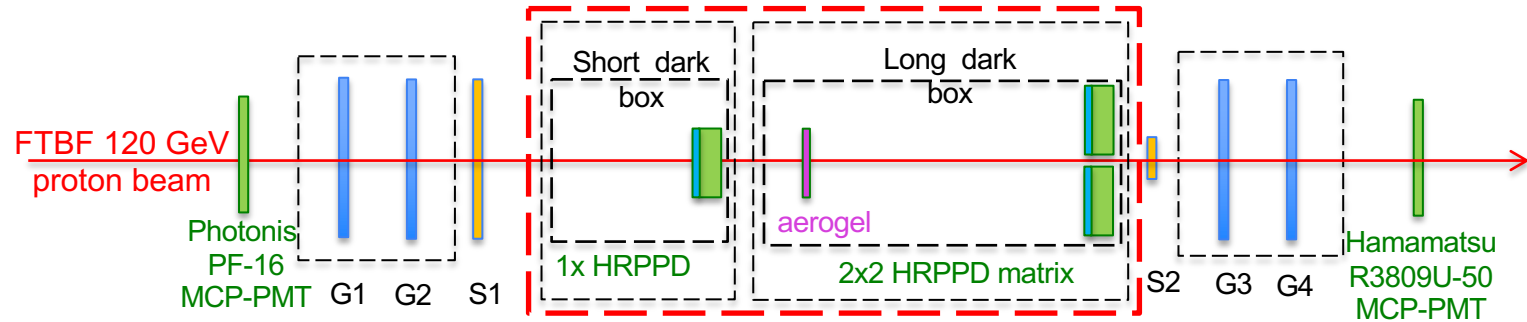
pfRICH prototype @ CRT

Our test beam plan C from February 2024

- De-couple vessel / mirror PED effort and the May 2024 beam test entirely
 - Implies using existing custom dark box(es) & no mirrors -> see next slide
 - Vessel / mirror work can then be comfortably concluded in summer 2024
- (Conditionally) give up π/K separation and only work with 120 GeV primary protons
 - Less equipment to take care of (no need in a separate DRS4 DAQ setup for beamline Cherenkov counters, etc)
 - Doable in one week; we would probably even be able to make a measurement without a GEM tracker (?)
- Give up porting pfRICH software to dd4hep for the beam test purposes
 - Adjust standalone code; one critical dependency less
 - More workforce / time available for other preparations, but also for the vessel / mirror effort
- Effectively save a month of April for other work
 - Because pretty much no pre-assembly (at Stony Brook) is required

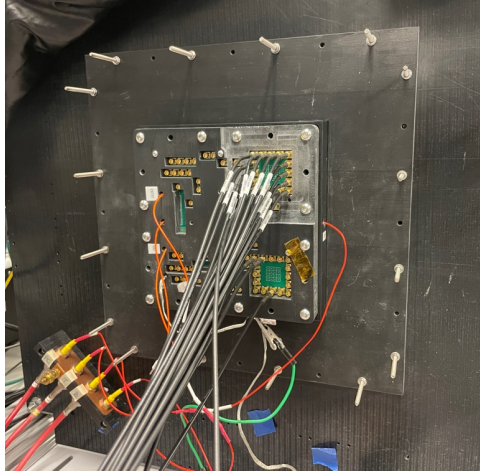
Plan C from February 2024: test setup @ Fermilab

- $\langle n \rangle \sim 1.040$ means a saturated Cherenkov photon angle ~ 278 mrad
- Assuming ~ 400 mm expansion volume, need to measure (1) a ring of ~ 114 mm radius ...
- ... and (2) timing of a “photon flash” in HRPPD window from a proton passing through it

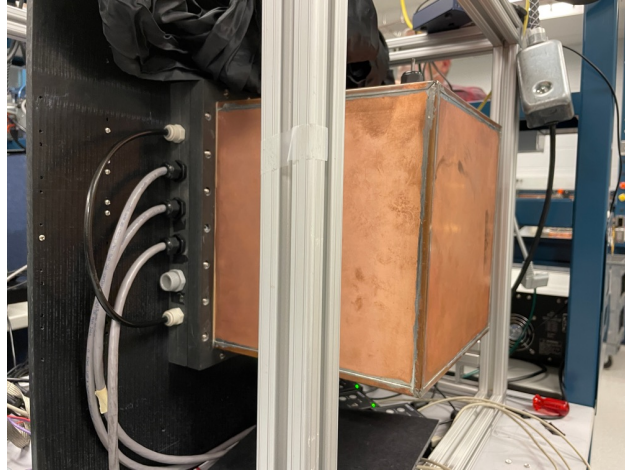


- **Main deliverable** is a direct simultaneous demonstration of
 - $\langle N_{pe} \rangle$ & a saturated Cherenkov angle resolution @ 120 GeV, with and without acrylic filter
 - HRPPD performance as a t_0 reference sensor for ePIC ToF subsystems
 - < 50 ps timing resolution using aerogel Cherenkov photons
 - $O(20\text{ps})$ timing resolution using sapphire window Cherenkov photon flashes

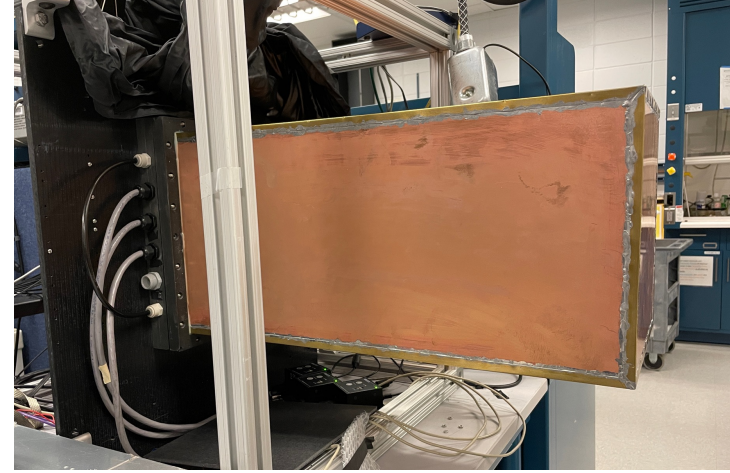
Plan C: “equipment” available at BNL



rear side plate with a single HRPPD



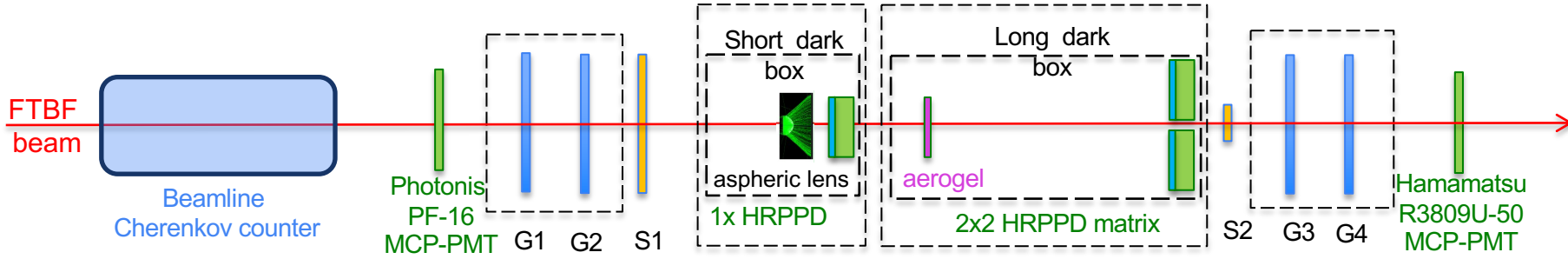
front side with a short 9" dark box



front side with a long 22" dark box

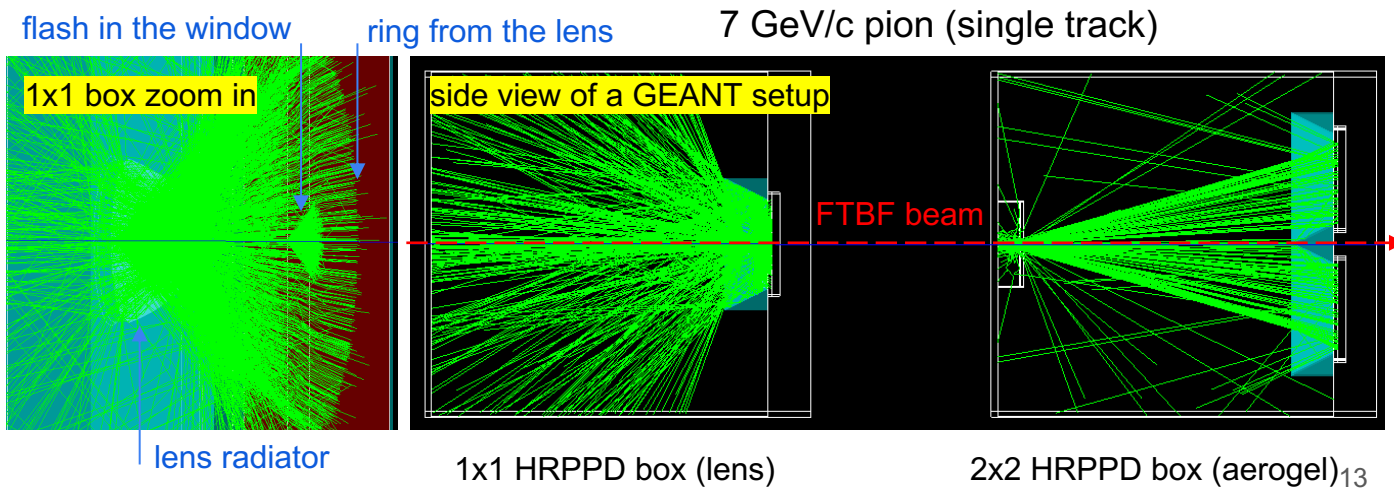
- A long dark box cover has a square opening of 262mm x 262mm
 - Obviously sufficiently wide to place a 2x2 matrix of 120mm x 120mm HRPPDs ...
 - ... and see an un-obscured ring with a ~230mm nominal diameter
 - Obviously sufficiently long to imitate a ~400mm long pfRICH expansion volume
- Will need to design and 3D print a 2x2 HRPPD mounting plate (considered a trivial task)

pfRICH standalone code update given on 02/01/24



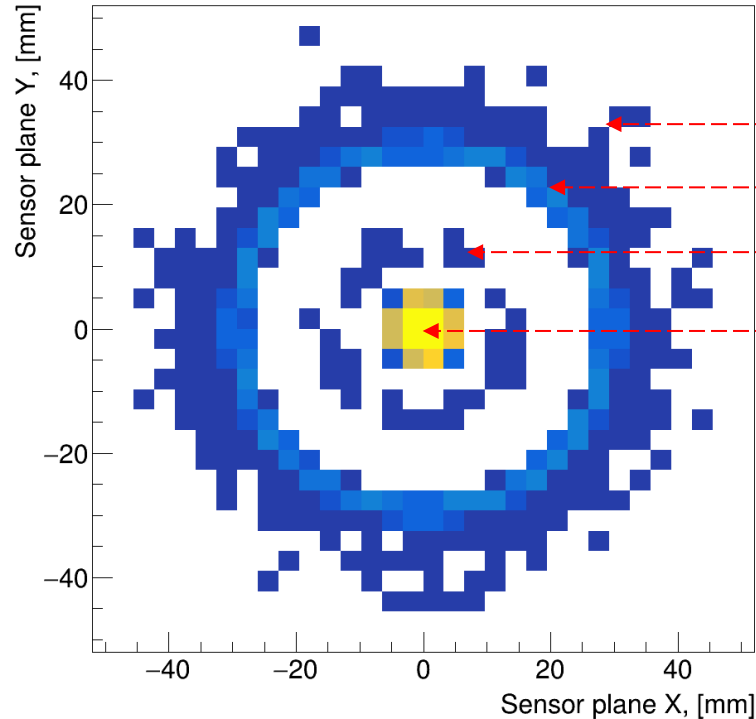
➤ Unify three setups (ePIC final, FTBF beam test “plan C”, QA station optical head) in one repo

```
[ayk@mbeach pfRICH]$ ls -l
total 92
drwxrwxr-x 5 ayk ayk 4096 Jan 31 13:29 build
-rw-r--r-- 1 ayk ayk 5491 Jan 31 13:29 CMakeLists.txt
drwxrwxr-x 2 ayk ayk 4096 Aug 14 08:01 curves
drwxrwxr-x 2 ayk ayk 4096 Mar 10 2023 database
drwxrwxr-x 4 ayk ayk 4096 Jan 28 10:54 epic
drwxrwxr-x 2 ayk ayk 4096 Mar 5 2023 examples
drwxrwxr-x 4 ayk ayk 4096 Jan 28 11:22 ftbf
drwxr-xr-x 4 ayk ayk 4096 Sep 26 2021 g4irt
drwxrwxr-x 2 ayk ayk 4096 Aug 25 10:06 gdml
drwx----- 2 ayk ayk 4096 Jan 28 12:07 include
drwxrwxr-x 2 ayk ayk 4096 Jan 29 09:10 macro
drwxrwxr-x 6 ayk ayk 4096 Feb 1 10:58 obsolete
-rw-r--r-- 1 ayk ayk 4434 Jan 28 12:29 pfRICH.cc
drwxrwxr-x 2 ayk ayk 4096 Mar 2 2023 png
-rw-rw-r-- 1 ayk ayk 487 Aug 15 13:46 README.AYK
-rw-rw-r-- 1 ayk ayk 3142 Mar 10 2023 README.md
drwxrwxr-x 2 ayk ayk 4096 Jan 30 11:18 scripts
drwxrwxr-x 4 ayk ayk 4096 Jan 28 10:53 share
drwx----- 3 ayk ayk 4096 Jan 28 11:00 source
drwxrwxr-x 2 ayk ayk 4096 Aug 18 21:11 tmp_00
drwxrwxr-x 4 ayk ayk 4096 Jan 28 17:59 tstand
```



FTBF setup: hit map in a 1x1 HRPPD box

7 GeV/c pions (100 tracks)

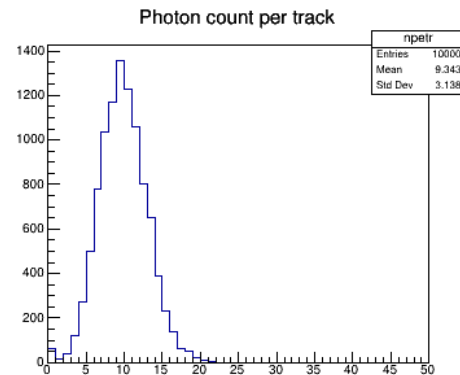
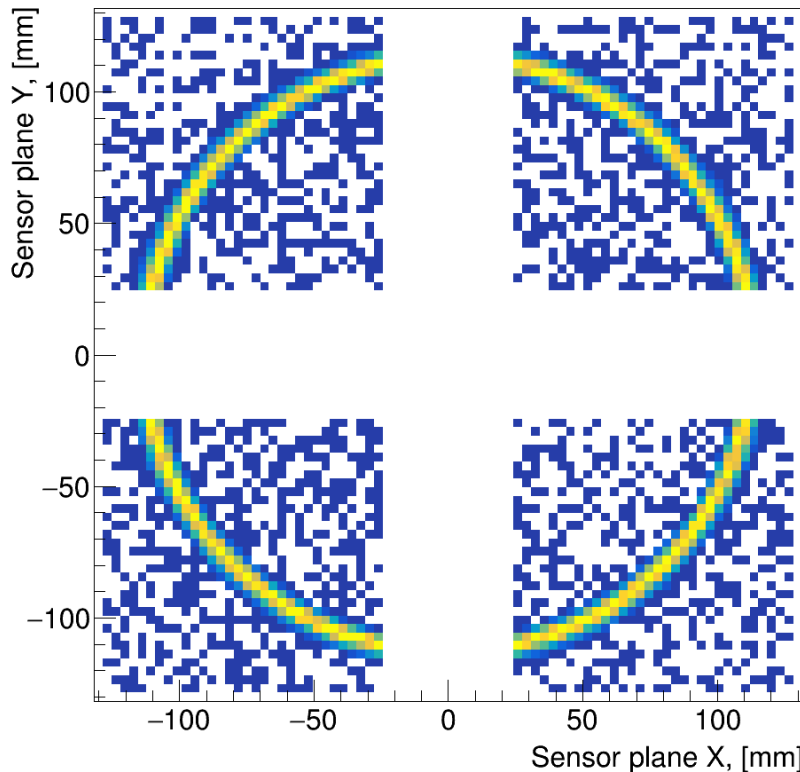


This part is most likely irrelevant for the CRT installation

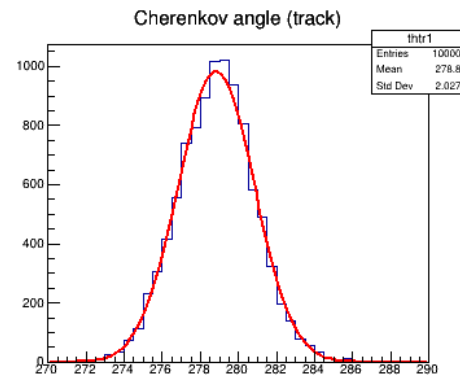
- photons produced & bounced in the aspheric lens
 - photons produced in the aspheric lens
 - photons produced & bounced in the HRPPD window
 - photons produced in the HRPPD window
- Photons from the lens are easy to identify
 - A narrow ring; **may require inversed geometry**
 - Their $\langle N_{pe} \rangle$ must be defined rather well
 - They have very small spread in timing
 - **May also require inversed geometry**

FTBF setup: hit map in a 2x2 HRPPD box

7 GeV/c pions (10000 tracks)



$$\langle N_{pe} \rangle \sim 9.3$$

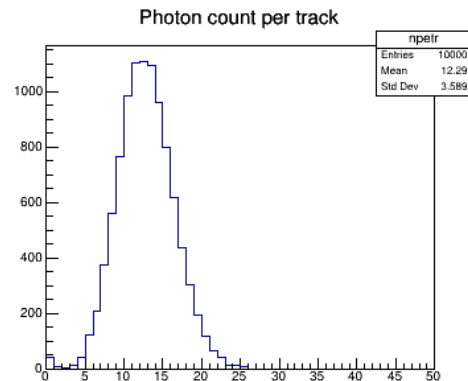
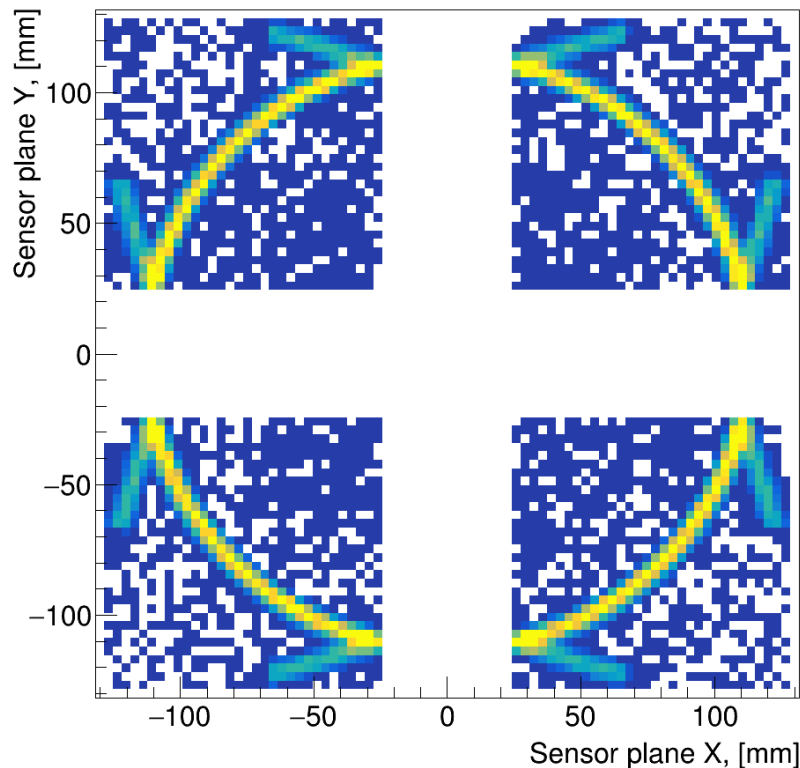


$$\theta_{TR} \sim 2.0 \text{ mrad}$$

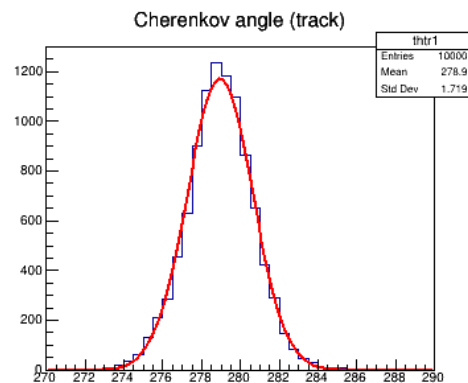
➤ Vessel length set to 450mm rather than 491mm (to better contain the light; see next slide)

FTBF setup: hit map in a 2x2 HRPPD box

7 GeV/c pions (10000 tracks)



$$\langle N_{pe} \rangle \sim 12.3$$

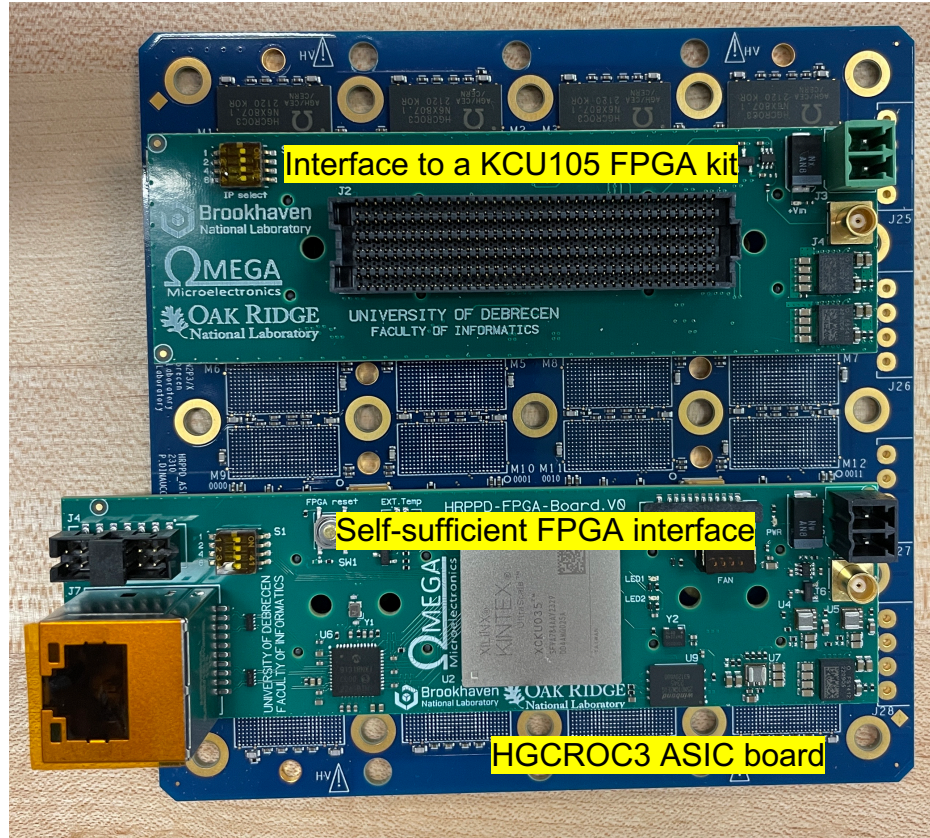


$$\theta_{TR} \sim 1.7 \text{ mrad}$$

➤ Same setup, with 90% reflective pyramid mirrors installed (~50mm x 50mm size would suffice)

HRPPD readout electronics

HGCROC3 ASIC backplane prototype



- A joint BNL / I2NP3 / Debrecen / ORNL effort in 2024
- A 1024 channel board (matches EIC HRPPD pixellation) + FPGA interface(s)
- Has hardware triggering capability
- This particular 4-ASIC prototype exists since quite some time; partly tested
- Interface to a KCU105 kit is certainly functional; FPGA board is “alive”
- Cooling system setup exists (five sets)
- A “TOA/ADC for HRPPDs” proof of principle measurement is pending
- A full version will have 16 HGCROC3 chips for a total of $16 \times 64 = 1024$ channels
- Will need ~\$50k for the CRT setup

A possible strategy

- Entertain the idea within the pfRICH DSC, with hpDIRC CRT team and EIC Project
- Make sure that HGCROC3 backplane prototype works with an HRPPD attached
 - We are not looking for an ultimate performance here, especially in terms of timing
- Verify counting rates, refine simulations (uniformly spread beam, etc)
- Come up with a concise formal proposal
- Build HGCROC3 backplanes for 4-6 HRPPDs
- Modify existing small dark box(es) in a way proposed for a 2024 Fermilab beam test
- Integrate pfRICH related hardware and DAQ into the existing CRT setup
- Timelines?
- Once there is a test beam opportunity (2026?), go there with a full-size vessel
 - With a knowledge that aerogel/HRPPD/readout work; together with the hpDIRC team?